Storage Policy for High Integration of Renewable Energy on the Electricity Grid

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Abstract

This paper will look the role energy storage plays as the country moves towards high integration of renewable energy on the electricity grid. We highlight energy storage technologies, emissions results of storage deployment, and regulatory and policy frameworks currently executed or under consideration.

Although energy storage has potential to increase emissions due to its primary role as an energy arbitrage technology, it is imperative to deploy storage in order to meet ambitious renewable energy goals. Both federal and state governments and regulatory agencies play a considerable role in investing in and deploying energy storage, while designing policies that ensure emissions reductions to enable decarbonization pathways.

We employ three case studies to showcase the need for clear legislative mandates to promote the deployment of energy storage in states and detail the pitfalls of perfunctory renewables and storage policy implementation, including needs for consumer protections, renewable energy deployment slowdowns, and cursory policy design.

Finally, our paper offers regulatory policy recommendations for state and federal actors based on our findings.

Executive Summary

This review of energy storage policy to enable high integration of renewable energy on the United States electricity grid is informed by some key assumptions. The Intergovernmental Panel on Climate Change recommends limiting warming to 1.5 degrees Celsius above pre-industrial levels to avoid the worst impacts of climate change, which means carbon emissions must be zeroed out by 2050, and then go negative. The amount of displacement of carbon emitting resources, plus the integration of electric heating and vehicles onto the grid, necessitates the drastically increased use of more variable renewable energy (VRE).

As VRE use increases, the grid will have to be modernized to enable such a high percentage of renewables on the grid. Energy storage will be a key piece of the grid modernization process, playing extremely important roles to ensure a reliable, stable, and modern grid, such as eliminating intermittency concerns, load shifting, and ultimately enabling high renewables integration.

Addressing Variability

Unlike traditional fossil fuel resources, which can deployed on demand, "variable" sources of energy like wind and solar power cannot be stored in their primary forms to be dispatched on demand, and are only available when the primary resource, such as wind or sunlight, comes into contact with the power technology. At certain times of high demand, VRE power plants may not be able to produce enough energy to meet customer needs. At other times, they may produce too much power, and generation will need to be curtailed.

However, it is important to note that, very few parts of the country currently curtail any renewable energy. In the United States, only about 10% of the electricity supply comes from VREs, and it won't be until the grid reaches approximately 40% VRE generation penetration that curtailment will need to be addressed. These variability problems are not immediately manifesting (with some exceptions in places like Hawaii and California which have very high levels of VREs already incorporated into their systems), but they are urgent, and lawmakers should begin designing frameworks to ensure that the expanding renewable energy market can be seamlessly integrated into the electricity grid without risking reliability. Large-scale energy storage will be a necessary technology to ensure that renewable energy curtailment is saved for times of high demand or low renewable power generation.

Energy Storage Technology

Understanding how different technologies have different discharge and capacity levels, and thus different applicability for energy storage, is important for understanding the energy storage market landscape. Information regarding discharge duration and technology types can be found in Figure 3 and Table 1.

Though this review takes a generally technology-neutral stance, this context is useful for understanding the market. Several technology types, while serving specific roles, are not experiencing particularly impressive growth projections. Pumped hydropower is the US's largest and oldest form of energy storage, but due to high capital costs and siting issues, it is unlikely to experience much growth. Flywheels and thermal technology face cost issues but may become relevant in the coming years as research, development and deployment bring costs down.

Hydrogen fuel cells can be very useful for long term seasonal storage, but costs are still too high for them to play a big role in the market. Today, lithium-ion batteries have seen falling prices, and have largely captured the storage market for the immediate future.

Energy storage is valuable in the context of emissions reductions because, in addition to smoothing out generation loads from renewable energy generation, it can replace “peaker plants,” which are power plants that supply additional capacity at times of high demand. Energy storage is a multifunctional resource that is often undervalued. Understanding its technological characteristics is useful to recognize the myriad revenue streams from which energy storage should benefit.

Not All Storage is Created Equally

Historically, energy storage has been used solely for energy arbitrage, and has led to increased emissions. Oftentimes, storage systems are charged by fossil fuel resources at times of low demand rather than via renewables during times of high generation. Today, because VREs are rarely curtailed due to the low fraction of generation they provide to the electricity grid, energy storage often pulls from other, more emissions-polluting forms of power generation.

This review of energy storage’s emissions impacts shows that energy storage must, in some way, be tied to renewable energy. Its value as an emissions reducer comes from its ability to rescue renewable energy that would otherwise be lost. Because most parts of the country rarely curtail VREs, it is difficult to attribute deployment of energy storage to driving growth of new VREs. However, due to the complexity of the policies and regulations that must be designed for the new storage market, it is important to build out infrastructure along with policy and regulatory frameworks now so that the electricity grid is prepared for the rapid renewables transition over the next decade.

Designing Policy and Regulatory Frameworks for Storage

To set up strong policy and regulatory frameworks for energy storage, properly valuing revenue streams is crucial. Table 2 shows that storage has more benefits in addition energy arbitrage. At every place across the value chain of the electricity market, storage has value. FERC’s new Storage Rule was designed to address proper storage valuation by asking that grid operators meet some minimum requirements and create market rules to ensure that storage is properly compensated and can compete with other energy sources. As of May 2019, grid operators were in the process of submitting compliance filings for FERC to review, which is expected to enable growth of the storage market.

There is some federal excitement around a no-strings-attached 30% Investment Tax Credit (ITC) for all energy storage. Wind and solar have benefitted from the ITC, which has been a valuable tool to help level the playing field for burgeoning, socially beneficial zero-carbon resources. However, with variables surrounding the emissions reductions benefits of storage, an ITC may need to be implemented cautiously. Rather than deploying as much energy storage technology as fast as possible, which is a valuable goal for renewables that have measurable emissions benefits, energy storage growth needs to happen in tandem with smart storage policy frameworks with the explicit goal of emissions reductions. At the same time, if building out a new industry to prepare for its coming emissions benefits is necessary, even if its short-term emissions benefits are not realized, an ITC would be a helpful way to jumpstart the industry.

While FERC regulates the wholesale market, states determine rules at the retail and end user level. Therefore, states have a large role to play in designing market parameters. This is especially in the case of restructured markets, in which states will have to determine if the storage systems should be considered a generation source or a transmission source, or both, and what that means for system ownership. States can also mandate the energy mix used in their state. State bodies will play a large role in determining if a new storage facility can be built in lieu of a new gas power plant.

It will often fall to the states to run emissions analyses to make sure new storage plants are actually helping reduce emissions rather than simply assuming that they will. Meanwhile, many states have adopted Renewable Portfolio Standards (RPS). Clearly defined parameters around the role of energy storage in meeting an RPS will be necessary to ensure that energy storage is closely tied to the decarbonization process.

Case Studies

This review assesses how California, Illinois, and Hawaii have incorporated energy storage as they seek to meet renewable energy goals. These states have unique electricity market designs from one another. Summaries and conclusions for each case study can be found starting on page 23.

Conclusions

Policy recommendations from this review include: ensuring that storage can be valued properly from all revenue streams; any incentive policies such as the ITC are designed with emissions reductions in mind; recognizing the importance of pairing storage with renewable energy rather than assuming that new storage will simply drive VRE growth; establishing strong oversight and clear protocols from state agencies; and considering consumer and ratepayer protections throughout the entire process. Overall, the creation of the new storage market should be done carefully and intentionally.

Cursory policy implementation without clear emissions goals and guidelines will not be helpful for decarbonization plans. The goal for storage markets should not simply be building out as much storage technology as possible, as is the case with renewable energy targets, but rather, designing storage markets with a framework that sets them up to help displace fossil fuel resources and enable renewables growth, balance their potential emissions increases, and succeed as the grid's primary flexible load capacity in the decades to come. Policymakers should resist the urge to design policy that simply builds out storage markets as fast as possible in the short term without regard to thoughtful design.

Introduction

The climate crisis threatens to cause catastrophic economic, ecological, and societal damage in the coming decades if global communities do not rapidly work to decarbonize their economies. The 2015 United Nations Framework Convention on Climate Change Paris Agreement shows that the world must limit the planet to 1.5 degrees Celsius of warming above pre-industrial levels[1] to stave off the worst effects of climate change.[2] This means that the world needs to aggressively decelerate its carbon emissions to zero by 2050.[3]

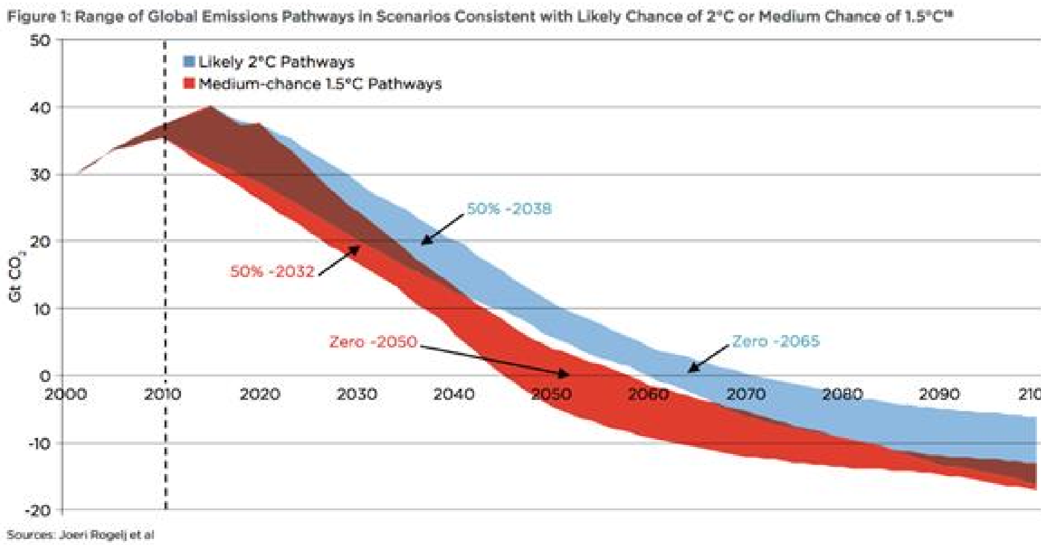

Figure 1: Staying below the suggested 1.5 degrees Celsius of warming will require carbon dioxide emissions to zero out by 2050. *Source: Joeri Rogelji et al.* [4]

Dramatically depleting carbon emissions by mid-century will involve a deep decarbonization strategy that effectively eliminates the use of fossil fuels as an energy source. At this time, many energy analysts agree that "electrify everything" is one of the most realistic ways to decarbonize, given that there are understood pathways to zero out carbon in the electricity sector.[5][6] That means, understandably, that electric capacity demands will rise as different market segments, such as transportation and building heating, are incorporated into the electricity sector.

[1] United Nations Framework Convention on Climate Change. (2016, November 4). Paris Agreement. Le Bourget, France.

[2] Pidcock, R. (2016, April 21). Scientists compare climate change impacts at 1.5C and 2C. Carbon Brief. from https://www.carbonbrief.org/scientists-compare-climate-change-impacts-at-1-5c-and-2c

[3] Oil Change International. (2016). The Sky's Limit(p. 13). Washington, DC. from http://priceofoil.org/content/uploads/2016/09/OCI_the_skys_limit_2016_FINAL_2.pdf

[4] Rogelj, Joeri, Michel den Elzen, Niklas Höhne, Taryn Fransen, Hanna Fekete, Harald Winkler, Roberto Schaeffer, Fu Sha, Keywan Riahi, and Malte Meinshausen. "Paris Agreement Climate Proposals Need a Boost to Keep Warming Well below 2 °C." Nature 534 (June 29, 2016): 631. https://doi.org/10.1038/nature18307.

[5] Roberts, D. (2017, October 27). The key to tackling climate change: Electrify everything. Vox. from https://www.vox.com/2016/9/19/12938086/electrify-everything

[6] Adams, N. (2018, May 8). Electrify Everything! A Practical Guide to Ditching Your Gas Meter. Retrieved July 23, 2018 from https://www.greentechmedia.com/articles/read/electrify-everything

During this electrification process, the electricity sector must begin a rapid transition along the decarbonization pathway. Ample solutions and recommendations have been put forth by research institutions and think tanks, but this paper will assume the most economically realistic, salient, and efficient solutions available today.[7] Carbon capture and sequestration is still a nascent technology that is not yet deployable to scale and is unlikely to play a significant role in a useful time frame,[8,9] and economic factors have led agencies like Energy Information Administration (EIA) to project that the share of nuclear generation, a zero-carbon resource, will actually decline by 2050.[10] All this means that we can expect to: (a) vastly expand our electric load demand and (b) considerably grow the amount of variable renewable energy (VRE) needed to meet this load in a carbon-free way.

According to historical growth data,[11,12] wind and solar power have seen exponential growth over the past decade, and projections from the National Renewable Energy Laboratory (NREL)[13] show that these energy resources will become dominant electric fuel sources in a carbon constrained world, *if* we choose to act. (Fig. 2) This transition will not come without its challenges, but they can be overcome and should not be considered insurmountable roadblocks in the decarbonization pipeline.

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[7] Deep Decarbonization Pathways Project. "Pathways to Deep Decarbonization 2015 Report," 2015. http://deepdecarbonization.org/wp-content/uploads/2016/03/DDPP_2015_REPORT.pdf

[8] Fehrenbacher, K. (2017, June 29). Carbon Capture Suffers a Huge Setback as Kemper Plant Suspends Work. Green Tech Media. https://www.greentechmedia.com/articles/read/carbon-capture-suffers-a-huge-setback-as-kemper-plant-suspends-work#gs.CH5Fhl8

[9] Holmes à Court, S. (2018, February 15). It'd be wonderful if the claims made about carbon capture were true. The Guardian. http://www.theguardian.com/commentisfree/2018/feb/16/itd-be-wonderful-if-the-claims-made-about-carbon-capture-were-true

[10] Michael Scott. "U.S. Energy Information Administration (EIA) Independent Statistics and : Nuclear Power Outlook," May 7, 2018. https://www.eia.gov/outlooks/aeo/npo.php.

[11] Solar Energy Industries Association. "Solar Industry Research Data | SEIA." SEIA, n.d. https://www.seia.org/solar-industry-research-data.

[12] American Wind Energy Association (AWEA). "Wind Energy Facts at a Glance." American Wind Energy Association, n.d. https://www.awea.org/wind-101/basics-of-wind-energy/wind-facts-at-a-glance.

[13] Cole, Wesley, Will Frazier, Paul Donohoo-Vallett, Trieu Mai, and Paritosh Das. 2018. 2018 Standard Scenarios Report: A U.S. Electricity Sector Outlook, Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-71913. https://www.nrel.gov/docs/fy19osti/71913.pdf.

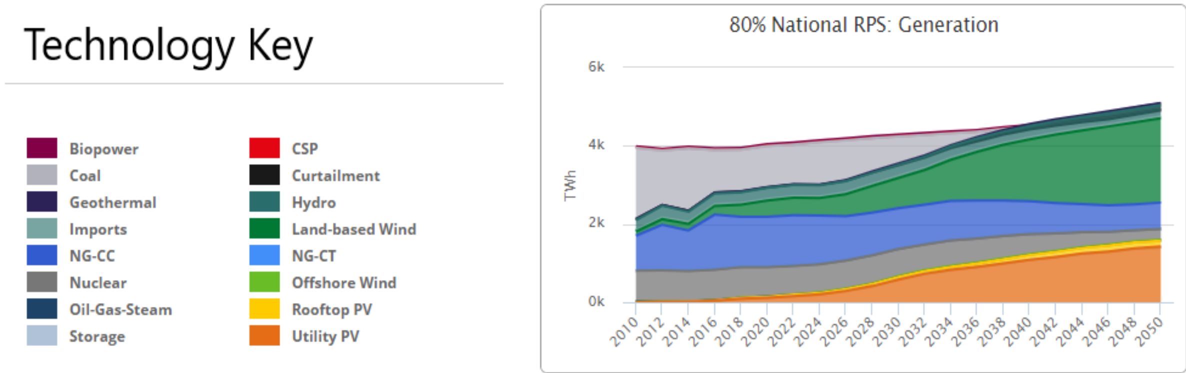

Figure 2: NREL's Standard Scenarios Results Viewer with consideration of an 80% National RPS, without accounting for vehicle and heating electrification. *Source: NREL*[14]

Wind and solar power are VRE resources. This means they are non-dispatchable; they cannot be turned on, increased, or controlled at a moment's notice in the same way that tangible fuel sources, like coal or gas that must be combusted in power plants, are. However, there are numerous ways that these issues can be addressed through grid modernization, such as stronger transmission lines, systems for demand response, more regional interoperability, implementing non-wire alternatives, and more. Although these grid adaptations are all necessary aspects of the energy transition, one of the most crucial pieces to the puzzle of integrating high levels of VREs into the electric grid is tackling the implementation and operation of a large-scale storage industry.

Storage must play a key role in achieving high renewables integration on the grid quickly. This paper will review the barriers to deploying storage to scale while ensuring emissions reductions, federal and state level approaches to implementation, and present proposals and recommendations to overcome these challenges in a variety of markets, utility structures, and scales. The review will culminate in a toolkit for policymakers to ensure that policies and regulations that support the growth and deployment of storage for the explicit purpose of carbon reductions are made a priority in the transition to a low-carbon electricity market.

Today's Grid, Renewable Energy, and the Intermittency Issue

Energy storage systems are technologies that allow energy to be stored for use on demand. In the case of most fossil fuel resources, a lump of coal or a barrel of oil is essentially chemical potential energy stored in the bonds of the hydrocarbons that make up the material. However, renewable energy resources like wind and solar power are variable – these energy resources cannot be stored in their primary energy forms. Even though incoming solar radiation and wind patterns can be highly predictable, which has led to key innovations in siting, permitting, and design of these resources, they are not readily dispatchable for on-demand use at all times. Therefore, at high levels of VRE integration, there needs to be a solution to overcome this variability.

[14] Ibid.

It is important to caveat any discussion of renewable energy intermittency issues with the following: VRE's intermittency issues are often over exaggerated and used as fodder to discount their application.[15] A number of feasibility studies have even shown that much higher levels of renewables penetration than currently exist on the U.S. grid can be accommodated. For example, a recent study of the Midcontinent Independent System Operator (MISO) showed that under current grid conditions, which today handle almost 10% VRE, significant updates to the grid will not need to be addressed until there is an overall capacity mix of more than 40% VRE.[16] Meanwhile, the California Independent System Operator (CAISO), which runs 80% of the state's grid, has recorded successfully handling nearly 70% renewable sources, not including hydropower, at certain moments, and occasionally sees wind and solar accounting for almost half of all power production throughout the day. Normally, renewables make up a third of California's grid.[17]

That said, there are valid difficulties associated with integrating very high levels of VRE resources like wind and solar into today's grid. The United States' power grid was designed to handle large, centrally controlled power plants with dispatchable loads to meet demand at all times. The current grid was not designed for a system of variable, distributed point-source generation, and thus, figuring out how to make our electricity system run almost entirely on wind and solar can seem like trying to fit a square peg into a round hole. Grid operators have deeply ingrained planning methods to manage the daily operations of the electricity grid to ensure that all customers have affordable and reliable access to electricity. Operators handle this management by dispatching resources via a complicated series of day-ahead, hour-ahead, and real-time markets, responding to every change in end-user demand the moment it occurs, while simultaneously planning for different demand loads for the following day.

It is reasonable that within this challenging process, grid operators want to know that their electricity generation supply is readily available for dispatch at the moment it is needed. Sudden cloud cover over a solar farm in the middle of the day can cause output to unexpectedly drop for a few minutes and a change in wind speeds and directions can impact expected demand output, while grid operators know that an always-running coal-fired power plant will constantly chug along and produce power at a consistent rate regardless of most natural conditions. Uncertainty is a grid operator's biggest frustration,[18] and without further analysis, it would seem that high levels of variable renewables on the grid would aggravate uncertainty. However, these are not insurmountable challenges, and a carbon-free grid running predominantly on wind and solar can be made possible with key innovations and changes.

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[15] Shahan, Zachary. "Intermittency Of Renewables?... Not So Much." CleanTechnica, July 21, 2013. https://cleantechnica.com/2013/07/21/intermittency-of-renewable-energy/.
[16] Cook, Amanda. "Study: MISO Grid Needs Work at 40% Renewables." RTO Insider (blog), November 19, 2018. https://www.rtoinsider.com/miso-renewable-energy-study-106376/.
[17] Fracassa, Dominic. "California Grid Sets Record, with 67% of Power from Renewables." SFGate, May 18, 2017. https://www.sfgate.com/g00/business/article/State-breaks-another-renewable-energy-record-11156443.php?i10c.ua=1&i10c.encReferrer=&i10c.dv=8.
[18] Moreno, Rodrigo, Alexandre Street, José M. Arroyo, and Pierluigi Mancarella. "Planning Low-Carbon Electricity Systems under Uncertainty Considering Operational Flexibility and Smart Grid Technologies." Philosophical Transactions. Series A, Mathematical, Physical, and Engineering Sciences 375, no. 2100 (August 13, 2017). https://doi.org/10.1098/rsta.2016.0305.

In fact, there are several strategies for grid operators and utilities to consider, and governmental policies to implement in order to enable high renewables penetration on the grid without destabilizing the balance that operators must maintain. Steven Chu, former Energy Secretary under Obama, laid out a "laundry list to reform the grid,"[19] which included factors like reducing line congestion, interregional cooperation, nationwide transmission networks, addressing peak demand challenges, and perhaps most importantly, grid-scale storage.

Dr. Robert Fares, a postdoctoral fellow at UT Austin researching grid-connected battery energy storage systems, his 2015 piece in *Scientific American* refers to the "Law of Large Numbers" probability theorem as a way of providing predictability to an uncertain process: "the combined output of every wind turbine and solar panel connected to the grid is far less volatile than the output of an individual generator."[20] Even in moments when the sun isn't shining and the wind isn't blowing, it is *somewhere*. With strong transmission lines and the interregional cooperation, the aggregate output of large volumes of renewable energy means that the more VREs there are, the better they can balance on the grid and limit the amount of flexible reserve capacity necessary to meet demand and balance the grid at times of high demand.[21] That flexible reserve capacity is usually made up of natural gas plants that can ramp up quickly to meet demand. However, in a carbon-constrained world, it will be necessary to avoid the need for *any* fossil fuel powered generators, including natural gas.

Enter energy storage: storage systems facilitate excess renewable energy generation, grid dispatch, and storage of whatever is leftover in a potential energy form. Just as fossil resources are chemically stored energy in the form of hydrocarbon bonds to later be combusted to create heat that will drive a process that creates electricity, storage systems can store the potential energy from the sun or wind in many forms: within the charge of a battery, in water that has been pumped up a hill to be released when needed, or even within the bonds of a hydrogen atom. In order to make the grid as compatible as possible with high renewables integration, it is necessary that current energy generation shortfalls can be met through large-scale storage of excess VRE capacity.

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[19] Bakke, Gretchen. The Grid: The Fraying Wires between Americans and Our Energy Future. New York, NY: Bloomsbury, 2016.

[20] Fares, Robert. "Renewable Energy Intermittency Explained: Challenges, Solutions, and Opportunities - Scientific American Blog Network." Scientific American, March 11, 5. https://blogs.scientificamerican.com/plugged-in/renewable-energy-intermittency-explained-challenges-solutions-and-opportunities/.

[21] Diakov, Victor, and Cole Blvd. "Tshe value of geographic diversity of wind and solar: stochastic geometry approach." National Renewable Energy Lab, n.d. https://www.nrel.gov/docs/fy12osti/54707.pdf.

Energy Storage in Context

Energy storage technologies can be somewhat esoteric, even to those with expertise in energy and electricity markets. Different technologies vary in discharge duration and power output, and thus have different functions and levels of applicability to addressing large-scale electricity storage. Here, we present a brief explanation of different energy storage technologies as a basis for understanding the technology. (Fig 3. and Table 2.)

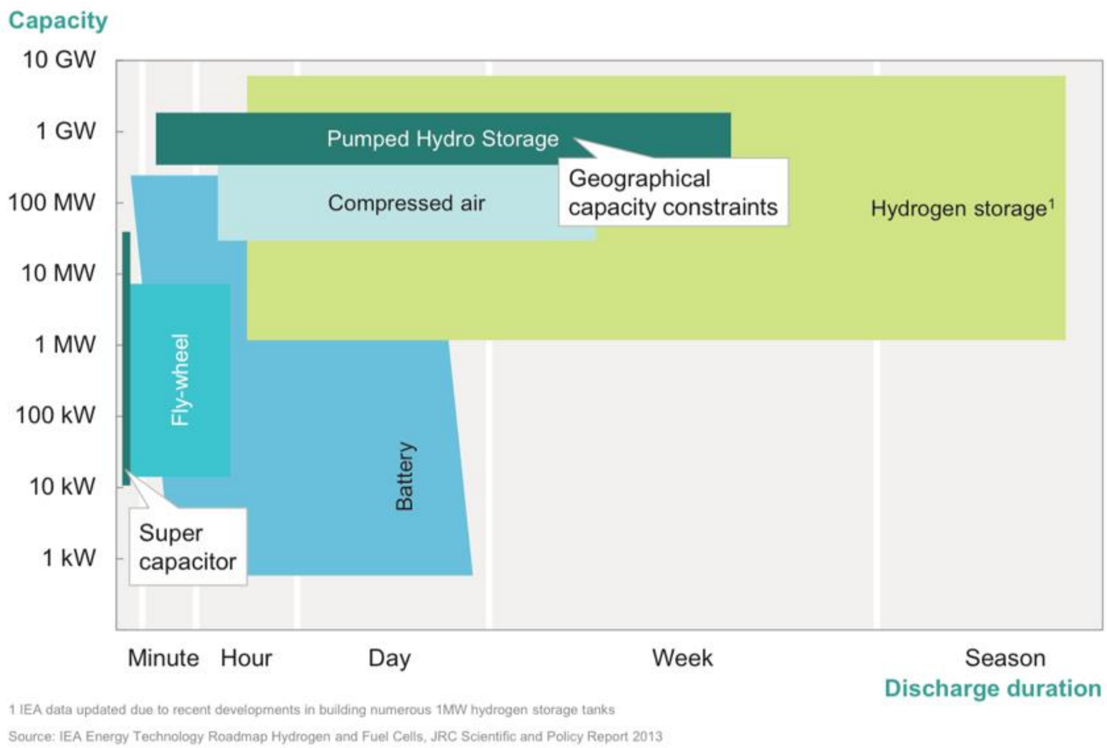

Figure 3: International Energy Agency (IEA) data on storage type capacity by discharge duration.[22]

[22] International Energy Agency. "Technology Roadmap: Hydrogen and Fuel Cells." International Energy Agency, 2015. https://www.iea.org/publications/freepublications/publication/TechnologyRoadmapHydrogenandFuelCells.pdf.

Table 1: Energy Storage Technologies Summary Chart

Technology type	Summary	Discharge Duration[1]	Application	Current relevance to the growing energy storage market
Batteries	Involves rechargeable batteries that store energy as electron rich chemical energy. Lithium ion batteries are the leading grid-scale storage system technology.	4-8 hours	Electric vehicles, grid energy storage, behind the meter storage, transmission and peaker replacement.	High – projections include nearly 1000 GW of capacity by 2040 and $620 billion in investments.[2]
Flywheels	Convert kinetic energy into electricity through a spinning rotor. Flywheels store electricity as rotational energy, which is released in quick bursts of energy or at lower power for a slightly longer duration of time.[3]	Minutes	Industrial mechanical equipment, microgrid storage, peaker replacement, frequency regulation.	Low-moderate – utilities and grid operators have shown interest, but it is not currently a dominant large-scale energy storage system.
Pumped Hydropower	Mature technology that has been deployed in the US since the 1890. Dominant form of energy storage technology in the world. The efficiency of pumped hydro and vary dramatically depending on the age of the system.[4] Limited by permit process and high capital costs.	Long-term/ seasonal	Large hydropower dams, provide grid scale power and energy storage capabilities as a transmission system.	Low - limited availability for siting, substantial upfront capital investments. Very little investment in new hydropower.
Compressed Air Energy Storage (CAES)	Stores air under pressure. When electricity needs to be generated, the pressurized air is heated and drives a generator. CAES is often limited by economic constraints.	Long-term, seasonal	Require very large storage areas, such as salt caverns, and can be used for grid scale energy storage.	Low - there are only two utility-scale operational systems worldwide.
Thermal	Compresses air into a liquid form to be discharged at a later time. Still an emerging technology with some prototypes in operation.	Long-term/ seasonal	Solar thermal power plants (Concentrating Solar Power), molten salt storage, pumped heat electricity storage.	Low – some existing systems, but economic and technical challenges to future implementation.
Hydrogen Energy Storage/ Hydrogen Fuel Cells (HFCs)	Technically a form of Thermal energy storage created by converting energy into hydrogen molecules via electrolysis. Extremely high energy density, can be re-electrified and slowly discharged in fuel cells or combusted in power plants.	Potential for long-term/ seasonal	Fuel cell vehicles, large grid-scale storage in caverns, transmission system or peaker replacement.	Low – but with some potential. Though not yet marketable, HFCs may become an important storage option in the coming decades.
Supercapacitor	A capacitor with rapid charge/discharge cycles for short-term energy storage or burst-mode power delivery.	Seconds – immediate discharge duration	Cars, trains, buses, construction equipment, elevators, regenerative breaking.	Low - not applicable for necessary long-term discharge duration.

[1] Schiller, M. 2014. Hydrogen Energy Storage: A New Solution To the Renewable Energy Intermittency Problem. Renewable Energy World. Referred 20.1.2017
[2] Henze, Veronika. "Energy Storage Is a $620 Billion Investment Opportunity to 2040." *BloombergNEF*, November 6, 2018.
[3] Wood, Laura. "Global Flywheel Energy Storage Market Trends, Analysis & Forecast 2018-2022." *Research and Markets*, April 19, 2018.
[4] California Energy Commission. "California Energy Commission - Tracking Progress," August 2018.

Today, batteries have largely captured the storage market as a technology in which prices are falling dramatically.[23] Flywheels and thermal technology, including hydrogen cells, have not yet seen price drops that would make these technologies cost competitive and allow them to build out large viable markets. While battery-powered electric vehicles took over the transportation market for new light vehicles and the price of lithium-ion batteries dropped dramatically, hydrogen fuel cells (HFCs) remained largely in the R&D space. However, HFCs might still be a useful tool for storage via thermal integration in the coming years as technology improves and costs fall. Experts at NREL predict that hydrogen storage is at least five years away from anything marketable,[24] but HFCs could be an important pathway for seasonal storage because unlike batteries, which have a discharge duration of about 2 to 12 hours, hydrogen storage has a low rate of self-discharge and can thus be applicable for long term, even seasonal, storage.[25]

For the purposes of this paper, we will remain generally technology agnostic, with the understanding that batteries have a hold over the current energy storage market, which has grown to 900 MW of cumulative capacity from close to nothing in 2010.[26] However, battery storage dominance could change in the coming years assuming other technologies fall in price to the point where their technological benefits are realizable. Essentially, we will consider "storage" to mean the most prominent and commercially available storage technologies today, which often, but not always, refers to battery technology.

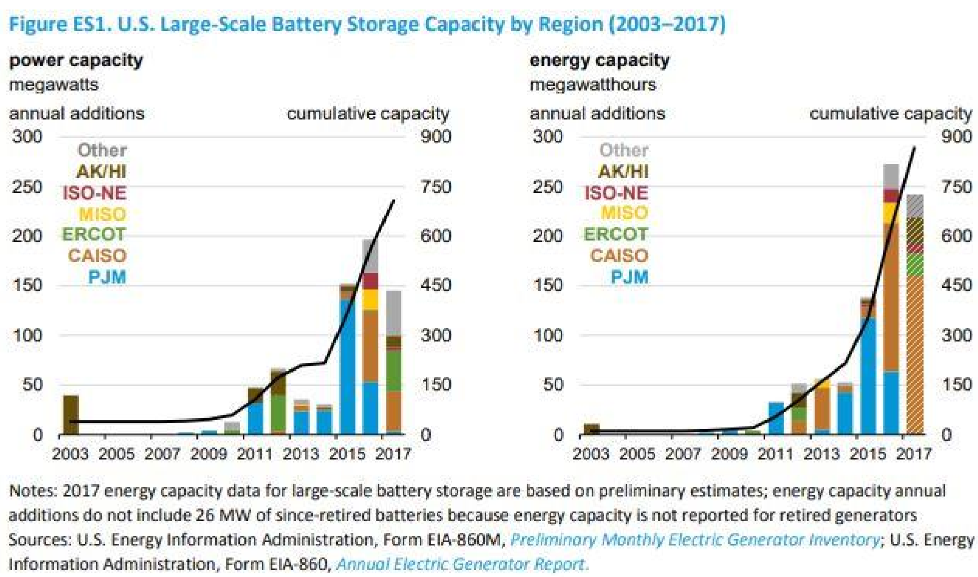

Figure 5: EIA's figures on battery storage generation capacity and energy capacity growth since 2003

[23]Consulting.us. "Falling Battery Prices Unlocking New Opportunities in Electric Grids, Says Deloitte." Consulting.us, December 4, 2018. https://www.consulting.us/news/1370/falling-battery-prices-unlocking-new-opportunities-in-electric-grids-says-deloitte.
[24]Interview with strategic energy analyst at NREL, February 21, 2019.
[25]Pellow, Matthew A., Christopher J. M. Emmott, Charles J. Barnhart, and Sally M. Benson. "Hydrogen or Batteries for Grid Storage? A Net Energy Analysis." Energy & Environmental Science 8, no. 7 (2015): 1938–52. https://doi.org/10.1039/C4EE04041D.
[26] U.S. Energy Information Administration (EIA). "U.S. Battery Storage Market Trends," May 2018, 32. https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage.pdf.

According to predictions by researchers at NREL, by 2020, new battery storage systems will have a lower cost than new combustion plants.[27] Data is showing that soon, within national markets, storage will be the lower lifecycle cost option than gas power plants to serve as flexible generation alongside high renewable energy integration on the grid.[28] Not only is storage cost competitive, it also fits in well with existing grid infrastructure. With proper energy management systems and meter management systems, there should be no grid interconnection issues. In fact, most storage mechanisms, including batteries, are more flexible than traditional peaker plants,[29] so utilities should already be looking to battery storage systems rather than building new fossil fuel-fired power plants to meet peak demand needs.

Lazard's Levelized Cost of Storage Analysis - Version 4.0 presents a deep dive into the "observed costs and revenue streams associated with commercially available energy storage technologies."[30] Its findings show that energy storage technology and implementation costs have fallen significantly, recognizing that shorter-duration battery technology (those with a discharge rate of under four hours) are the most cost effective and commercially viable option. Despite falling costs and increasing revenue returns, many storage projects are dependent on incentive programs and subsidies. However, the flexible application of storage makes it difficult for investors to understand the value of something that has so much multi-functionality, and the lack of regulatory and value clarity mean that revenue streams are poorly understood and often undervalued.[31]

Throughout this paper, we will examine the challenges related to storage deployment and operation, ways to overcome barriers, and the regulations and policies that enable storage in the market today. We will then use this to consolidate information on regulatory, policy, and market conditions that can help make storage succeed to ultimately replace fossil fuel peaker plants, enable higher percentages of renewable energy on the grid, and phase out fossil fuels by making the intermittency of renewables an irrelevant factor when adding new capacity and decommissioning old fossil fuel-powered plants.

Storage – Not Inherently an Emissions Reducer

A series of papers from Eric Hittinger, professor and researcher at Rochester Institute of Technology, show that energy storage application has, unexpectedly, historically increased emissions.[32] While these studies may initially appear to undercut our thesis that enabling more energy storage should unlock the potential of renewable energy and lead to grid decarbonization,

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[27] Supra 23
[28] Manghani, Ravi, and Lon Huber. "Energy Storage: Evolution and Revolution on the Electric Grid," March 29, 2018. http://www.ncsl.org/Portals/1/Documents/energy/webinar_energy_storage_final2_32165.pdf.
[29] Supra 23
[30] Wilson, Mark. "Lazard's Levelized Cost of Storage Analysis," November 2018, 60. https://www.lazard.com/media/450774/lazards-levelized-cost-of-storage-version-40-vfinal.pdf.
[31] Zame, Kenneth K., Christopher A. Brehm, Alex T. Nitica, Christopher L. Richard, and Gordon D. Schweitzer III. "Smart Grid and Energy Storage: Policy Recommendations." Renewable and Sustainable Energy Reviews 82 (February 1, 2018): 1646–54. https://doi.org/10.1016/j.rser.2017.07.011.
[32] Hittinger, Eric S., and Inês M. L. Azevedo. "Bulk Energy Storage Increases United States Electricity System Emissions." Environmental Science & Technology 49, no. 5 (March 3, 2015): 3203–10. https://doi.org/10.1021/es505027p.

it is actually just an indication of the necessity for strategic application of the technology. Batteries are not inherently emissions reducing. The carbon emissions effect of storage is dependent on what technology the storage system is charged by, what would be providing electricity otherwise and what the storage system displaces, and which types of technology they enable. Policymakers and renewable energy advocates that seek to make storage a tool for enabling the clean energy transition must be aware of the function of storage and cognizant of how to grow the sector. This further solidifies the need for a thorough inspection of strategic storage deployment with a primary motivation of enabling renewable energy growth with a strong policy framework to ensure that the technology is working towards decarbonization.

If storage is to live up to its potential ability to facilitate a decarbonized electricity grid, it requires a "no regrets policy" -- one that errs on the side of caution, thinking and planning for the long-term, and building something that truly generates the benefits of decarbonization that it seeks to provide. Hittinger's papers explain that when storage is used and valued exclusively for energy arbitrage - purchasing and storing electricity from any power producer, including coal plants producing cheap and unused energy at night, when the price is low and generation is high to sell at another time when production prices are high - it is very common that emissions rise thanks to increased usage of carbon-intensive fuel sources to charge the storage system. Meanwhile, the value of storage as a tool for minimizing variability of renewable energy is mostly of value when there is more energy being produced from wind and solar than can be consumed.

With the occasional exceptions of California and Hawaii, which have been seeking ways to smooth out the "duck curve,"[33] there is rarely enough renewable energy being pumped into the grid that significant VRE curtailment, which is lost zero-carbon energy that could be stored, is necessary. Hittinger's research answers the question of how much wind and solar is actually needed to "realize emissions benefits from storage."[34,35] His studies estimate that value to be 35% of the total generation capacity in MISO - the wholesale market serving much of the Midwest, which had only around 9% generation from all renewables in 2018.[36] Once a grid operator needs to start regularly curtailing production from renewable resources, storage begins to realize its incredible value as a tool to maximize generation from wind and solar at high levels, while also not using a fossil-fuel intensive charging source.

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[33] The "duck curve" is a graph used to show electric power production by time in the day, showing a 24-hour period from midnight to midnight. The curves on the graph show power production and load demand. In the case of solar power production and load, the graph resembles the shape of a duck due to the imbalance between production throughout the day and time of peak demands (usually in the evenings). The "duck curve" of solar generation necessitates the use of generation-shifting technologies like storage.

[34] Goteti, Naga Srujana, Eric Hittinger, and Eric Williams. "How Much Wind and Solar Are Needed to Realize Emissions Benefits from Storage?" Energy Systems, December 11, 2017. doi.org/10.1007/s12667-017-0266-4.

[35] Hittinger, Eric, and Inês M. L. Azevedo. "Estimating the Quantity of Wind and Solar Required To Displace Storage-Induced Emissions." Environmental Science & Technology (ACS Publications) 51, no. 21 (2017): 12988–97. https://doi.org/10.1021/acs.est.7b03286.

[36] MISO. "MISO Market Data." Market Reports, December 31, 2018. https://www.misoenergy.org/markets-and-operations/real-time--market-data/market-reports/#nt=%2FMarketReportType%3ASummary%2FMarketReportName%3AHistorical%20Generation%20Fuel%20Mix%20(xlsx)&t=10&p=0&s=MarketReportPublished&sd=desc.

Hittinger's studies do note that "storage may enable more renewable generation, resulting in indirect reduction in total emissions. This indirect effect, where new storage provides conditions that support the addition of new wind and solar, is complex and hard to quantify."[37] Although there are not yet sophisticated analyses to measure the indirect benefits of storage as a renewable energy market driver, it is likely that grid operators, who can be preoccupied with uncertainty from variable renewable energy, feel more favorable towards capacity additions of VREs when they know their outputs can be smoothed with co-located storage.[38] States are starting to understand the symbiotic solar plus storage relationship, noting how adding renewables gives a price signal to add more storage, which in turn can lead to more renewables deployment. According to the Solar Energy Industries Association (SEIA), the Arizona Public Service is adding a 65 MW solar plant coupled with a 50 MW battery system, while Xcel has been receiving bids for solar and wind plus storage projects at record-setting low-prices.[39]

At the same time, storage is not necessarily *needed* to drive renewable energy - Renewable Portfolio Standards are much more effective at driving more wind and solar implementation.[40] However, there is certainly value to building out a robust energy storage industry today, even if we are not yet at the point of curtailing and storing significant amounts of renewable energy, to ensure the technology works, its regulations make sense, and a solid framework for rapid expansion exists once it is needed. As our case studies exemplify, it is imperative that policymakers are forward-thinking in the deployment of storage. Building out storage now will avoid the complications of compromised grid reliability when working towards their high levels of renewable energy goals. Some states have already run up against these challenges, and policymakers should learn from those mistakes. Even if storage deployed today is charged by fossil fuels, its established market and infrastructure will make for a smoother transition to high penetration of renewable energy in the coming years.

To be clear, storage deployment should not be delayed until renewables become a significant portion of generating capacity. Instead, this research should be a cautionary warning on the importance of building out prudent, flexible storage policy and regulation that asserts long term thinking and thorough carbon emissions analyses. A successful storage policy will consider not only the deployment of storage, but also have a heavy focus on the management and charging sources of storage. Cursory policy design for rapid scale-up of the industry may see short-term investment returns, but eventually fails to address energy storage's most vital function: enabling a carbon free electricity grid.

Consumer Protection

The purpose of this paper is to discuss the role that energy storage can play in achieving carbon emissions reduction goals, but we would be remiss if we did not briefly discuss the importance of consumer protection throughout the development and implementation of an expanding energy storage market. Our research came up against issues of consumer protection

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[37] Supra 34
[38] Kosowatz, John. "Energy Storage Smooths the Duck Curve." ASME, June 2018. https://www.asme.org/engineering-topics/articles/energy/energy-storage-smooths-duck-curve.
[39] SEIA. "Solar + Storage." Solar Energy Industries Association, n.d. https://www.seia.org/initiatives/solar-plus-storage.
[40] Roberts, David. "The Most Effective Clean Energy Policy Gets the Least Love." Vox, October 21, 2017. https://www.vox.com/energy-and-environment/2017/9/27/16365290/renewable-energy-standards-are-working.

when building any new capital asset, especially in the case of privately-owned utilities in deregulated markets. Due to the unique ways that utilities make a profit, they are essentially incentivized to increase their rate base (the value of the utility's assets) by making unnecessary investments. This can come by way of a utility claiming it needs to build a new substation or transmission line, when in reality its main motivation may be trying to get a higher rate base to receive a higher rate of return to make a higher profit.

Energy storage folds in to the consideration of consumer protection in a handful of ways. On one hand, utilities could start calling for storage projects, even when storage is unnecessary or is designed in inefficient and unnecessarily complicated ways with all sorts of infrastructure built out around them (see the Illinois case study below) in order to enlarge the rate base and increase the cost of electricity for consumers. On the other hand, energy storage systems could be a cheaper alternative to expensive new transmission lines or peaker plants and could enable lower electricity prices for consumers. Either way, it is not inherently in the investor-owned utility's best interest to build infrastructure that is financially beneficial to the ratepayer.

While the issues associated with utility business models in relation to customer rates are not a topic of focus for this paper, it highlights the need for energy storage deployment to be done properly and for policymakers to consider consumer protections throughout the process. It is up to legislators and agencies to make sure that laws are written to require Public Utility Commissions (PUCs) to oversee utilities in way that ensures they are not exploiting their customers. With hasty policy, consumers could end up paying much more than is necessary to meet carbon pollution emissions reduction goals. The purpose of addressing climate change impacts is to protect ordinary people and future generations, so storage deployment that makes carbon pollution emissions reductions more expensive than necessary would defeat that goal by harming ratepayers.

New Storage Rules and Incentives to Unlock Storage Barriers

The Federal Energy Regulatory Commission (FERC) Order 841, "Electric Storage Participation in Markets Operated by Regional Transmission Organizations (RTOs) and Independent System Operators (ISOs)" (the Storage Rule)[41] requires that RTOs and ISOs design market rules that enable storage resources to participate in wholesale markets and includes some minimum requirements that RTO/ISOs must meet, while leaving the rest of the proposal and implementation of new market rules up to them. The new storage rule is significant because it establishes a way for system operators to recognize the value of storage in multiple markets, such as energy, capacity, and ancillary services markets, while offering RTO/ISOs the flexibility to set up a system that works for their respective regions.

Many papers on storage deployment and best practices have argued for the necessity for storage to be valued and compensated properly for all the benefits it provides to the grid and for

[41] Federal Energy Regulatory Commission. "Electric Storage Participation in Markets Operated by Regional Transmission Organizations and Independent System Operators," February 15, 2018. https://www.ferc.gov/whats-new/comm-meet/2018/021518/E-1.pdf?csrt=14202011983284008755.

eliminating barriers to multiple revenue streams.[42,43,44,45] The Institute for Policy Integrity's report, "Managing the Future of Energy Storage,"[46] provides an excellent summary of how storage can add quantifiable value at each level of the grid, exhibited in Table 2. While storage's value has mainly been realized as energy arbitrage, it can provide huge benefits to the grid system at every level. In sum, the system as designed was not built with storage technology in mind, and it is necessary that grid operators be flexible and willing to change and learn to ensure responsible and beneficial storage integration onto the grid. A new design framework for storage that veers away from the traditional design of siloed grid operations is key to unlocking responsible storage deployment.

There has historically been concern, mostly from regulators, that allowing multiple revenue streams for storage technology will allow for double-compensation, which has hindered the ability to create policy that allows storage to receive multiple value streams. The Storage Rule does acknowledge this as an issue, but ultimately concludes that with a good framework, there are ways to ensure that value is not double-counted. In fact, the issuance of the Storage Rule intends to address exactly that; it requires grid operators to develop a framework that will integrate multiple revenue streams, while ensuring they have created a system that properly accounts for value and does not over- or double-count. Under the value stack approach, which is being used by New York State's Public Service Commission for distributed energy resources including behind-the-meter storage, revenue accounting is unambiguous and should exemplify how realistic it is to avoid double-compensation. The referenced report from the Institute for Policy Integrity explains:

> "If, for example, a system is already being compensated for its energy value by the wholesale markets, the same system would not be allowed to get compensated for its energy value by any other retail program, but would be allowed to be paid for its distribution level benefits by a retail program. Similarly, if a system is already being paid for the environmental value directly, it would not be allowed to participate in additional programs such as renewable energy credit markets. Such a categorization would allow energy storage systems to be compensated for the full benefit they provide, while alleviating double compensation concerns."[47]

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[42] Berrada, Asmae, Khalid Loudiyi, and Izeddine Zorkani. "Valuation of Energy Storage in Energy and Regulation Markets." Energy 115 (November 15, 2016): 1109–18. https://doi.org/10.1016/j.energy.2016.09.093.
[43] Mclaren, Joyce. "Batteries 101 Series: Use Cases and Value Streams for Energy Storage | State, Local, and Tribal Governments." NREL, March 25, 2016. https://www.nrel.gov/state-local-tribal/blog/posts/batteries-101-series-use-cases-and-value-streams-for-energy-storage.html.
[44] Balducci, Patrick, M. Jan E. Alam, Trevor D. Hardy, and Di Wu. "Assigning Value to Energy Storage Systems at Multiple Points in an Electrical Grid - Energy & Environmental Science," 2018. https://pubs.rsc.org/en/content/articlelanding/2018/ee/c8ee00569a#!divAbstract.
[45] Fitzgerald, Garrett, James Mandel, Jesse Morris, and Hervé Touati. "The Economics of Battery Energy Storage: How Multi-Use, Customer-Sited Batteries Deliver the Most Dervices and Value to Customer and the Grid.," 2015. https://rmi.org/wp-content/uploads/2017/03/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf.
[46] Condon, Madison, Richard L. Revesz, and Burcin Unel. "Managing the Future of Energy Storage." New York, NY: Institute for Policy Integrity, 2018. https://policyintegrity.org/files/publications/Managing_the_Future_of_Energy_Storage.pdf.
[47] Ibid.

Industry expert Ravi Manghani, Research Director of Energy Storage at Wood Mackenzie, has stated that FERC's Storage Rule will "open the floodgates for storage participation."[48] Today, those floodgates are beginning to open, albeit slowly, as RTOs and ISOs submit their compliance filings for review and markets wait for program implementation.[49]

Storage deployment can benefit on the federal level from incentives such as tax credits. Currently, wind and solar energy receive a small subsidy in the form of the Investment Tax Credit (ITC), which allows for the deduction of a percentage of the cost of installation from federal taxes. According to SEIA, the ITC helped enable the growth of solar from just over 1 GW in 2010 to 65 GW at the start of 2019.[50] The ITC has been a valuable tool to help level the playing field for burgeoning, socially beneficial zero-carbon resources in an otherwise calcified energy marketplace centered around heavy subsidies for hydrocarbons.[51] However, storage's value doesn't necessarily mean avoidance of externalities and carbon emissions. This contrasts with renewable energy, in which the reduction of carbon emissions can be readily quantified. In the absence of carbon pricing, renewable energy should receive compensation for those benefits. If grid operators' compliance filings turn out well, storage's value should be properly compensated for all its benefits, including emissions avoidance. That said, the ITC isn't necessarily a tool for valuing aspects of an industry that aren't otherwise compensated, but rather a way to help jumpstart nascent technologies and develop mature markets. In this way, a storage ITC can be an extremely useful policy tool to grow the industry.

Meanwhile, understanding that not all storage is leading to emissions reductions[52] means that advocates of storage focusing on its role in enabling a clean energy future should be wary about crude implementation of such a policy. For the reasons mentioned above, a storage ITC will be a complicated yet useful way to expand the market, but it must involve parameters that encourage smart buildout of the industry. Storage's main value as an emissions-reducer comes from rescuing electricity specifically from VREs that would have otherwise been lost. Therefore, storage that charges predominantly from renewable energy, preferably a co-located system to reduce electrical losses, may deserve a stronger incentive than a system mostly engaging in energy arbitrage and charging from coal-fired power plants.

In April 2019, Representative Mike Doyle (D-PA) and Senators Heinrich (D-NM) and Gardner (R-CO) introduced legislation to amend the federal tax code to allow energy storage to be a standalone recipient of the ITC (currently, the ITC extends to energy storage paired with eligible solar PV systems), which has been lauded by clean energy industries.[53] While this

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[48] John, Jeff. "FERC Allows Energy Storage to Play in Nationwide Wholesale Markets." Greentech Media, February 15, 2018. https://www.greentechmedia.com/articles/read/ferc-energy-storage-wholesale-markets.

[49] Maloney, Peter. "As Grid Operators File FERC Order 841 Plans, Storage Floodgates Open Slowly." Utility Dive, December 11, 2018. https://www.utilitydive.com/news/as-grid-operators-file-ferc-order-841-plans-storage-floodgates-open-slowly/543977/.

[50] Solar Energy Industries Association. "Solar ITC Impact Analysis." Solar Industry Research Data. March 2019. Accessed May 01, 2019. https://www.seia.org/solar-industry-research-data.

[51] Whitley, Shelagh, Han Chen, Alex Doukas, Ipek Gencsu, Ivetta Gerasimchuk, Yanick Touchette, and Leah Worrall. "G7 Fossil Fuel Subsidy Scorecard: Tracking the Phase-out of Fiscal Support and Public Finance for Oil, Gas and Coal." Overseas Development Institute (ODI), June 2018. https://www.odi.org/publications/11131-g7-fossil-fuel-subsidy-scorecard.

[52] Supra 34

[53] John, Jeff St. "US House Introduces Energy Storage Tax Credit Bill," April 4, 2019. https://www.greentechmedia.com/articles/read/congress-introduces-energy-storage-tax-credit-bill.

legislation does not attribute different values to storage depending on whether it is charged by electrons generated by renewable energy or fossil fuels, it does have merit as a short-term mechanism to jumpstart the fledgling industry. As deliberation over the legislation proceeds, it may be valuable for policymakers and interest groups to modify the proposal in a way that would encourage the most beneficial implementation of storage from an emissions-reductions standpoint. Ultimately, from a climate perspective, storage's benefit is dependent on its ability to enable growth of new renewable energy that displaces fossil fuel emissions. An ITC that does not clearly lay out varying benefits of storage's usefulness in this way may not actually be contributing to the end goals that climate-conscious policy makers seek.

Table 2: Energy Storage Revenue Streams by Market Level, from Institute for Policy Integrity's "Managing the Future of Energy Storage"

At the generation level:	
Energy arbitrage	Purchasing wholesale electricity when the price is low and selling it when the price is high can help lower the total cost of meeting the electricity demand by reducing the need to generate electricity when it is costly to do so.
Resource adequacy	Charging during off-peak times and discharging during peak times can help meet resource adequacy requirements needed to ensure system reliability during system peaks, reducing the need for capacity investment.
Variable resource integration	Energy storage can help "firm" the variable output from a renewable generator by charging when there is not enough demand for the generator's output and discharging when there is need.
Management of must-take resources	Resources such as hydro, nuclear, and wind must be taken by the buyers regardless of market prices due to regulatory or operational constraints so storage can avoid them having to dump excess energy at low demand.
Frequency regulation	Grid instability is prevented by ensuring that generation is matched with consumer demand at every moment.
Ramping	Ramping counteracts the effects of varying renewable generation.
Spinning/non-spinning reserves	Reserves can provide extra generating capacity in the event of an unexpected energy shortfall.
Voltage support	Voltage must be maintained within an acceptable range to match demand.
Black start	Storage can be used to restore power station operation in the event of a grid outage.
At the transmission level:	
Congestion relief	Storage can reduce the bottlenecks caused at certain locations of the transmission system during high-demand times by discharging at those locations during those periods.
Transmission system upgrade deferral	Shifting the electricity demand to less congested times prevents system overload and reduces the need, the size, or the urgency of new investment in the transmission systems.
Improved performance	Voltage maintenance and increased capacity improve the overall functioning of grid transmission.
At the distribution level:	
Congestion relief	Reducing congestion during peak demand times avoids the need for costly upgrades.
Mitigate outages	Storage can discharge in the event of an unexpected power outage.
Consumers (behind the meter):	
Manage consumption	Lower bills by displacing consumption from peak to off-peak rates, if consumers face time-varying rates.
Storage	Store energy from behind-the-meter generation, such as rooftop solar.
Back-up power	Provides emergency power in the event of grid failure.

The Role of the States

Electricity is produced and sold in the wholesale market before is it is sold and distributed to end users via retail markets. While ISOs/RTOs and grid operators manage the wholesale market, which handles the contracts between energy producers (such as a wind farm or a coal plant) and utilities (or in some cases, an individual buyer such as a business), the retail market is determined at the state level and is typically either traditionally regulated or deregulated (competitive). While FERC, a federal agency, develops rules for the wholesale market, it is up to the states to determine the rules at the retail and end-user level, and state and local bodies like public utilities commissions (PUCs), public service commissions (PSCs), co-op boards, and municipal governments oversee their operations.

The complexities associated with various state and local structures for the retail-end of electricity distribution deserve attention regarding the deployment and operations of energy storage. While federal regulation of electricity markets covers important aspects such as interstate transmission lines and wholesale market rates, the state has authority over the distribution of electricity to end users as well as the structures of their electricity systems, which are highly relevant to storage deployment and operation. State PUCs have jurisdiction over generation rates, net metering, electricity rates for customers, and policies such as the Public Utilities Regulatory Policies Act (PURPA),[54] thus decisions about local power distribution come in mainly at the state level.

There are several other ways states can enable the growth of energy storage in lieu of new fossil fuel power plants. The Energy Storage Association (ESA) highlights value, access, and competition as key components to encourage storage deployment at the state level.[55] Just as FERC's Storage Rule seeks to capture the proper value of storage systems at the wholesale level, it is up to state policymakers to create accurate price signals in the retail market in tandem with the wholesale market, and develop clear protocols and quantification mechanisms to reflect accurate market compensation. ESA's memo encourages setting procurement targets, exploring distributed energy resource (DER) valuation for behind-the-meter storage, creating incentives and providing financial support, and working on cost-benefit studies as ways to identify the accurate value of storage. While there has been an emphasis on ensuring that wholesale and retail markets coordinate not provide double-compensation for the same service, it is worth exploring this more and not assigning arbitrary double-compensation status to a service without examining how a storage system may deserve both state credit and wholesale credit for a similar service. Regardless, unbundling value stacks for various benefits that a storage system provides is crucial to establishing clear rules and valuation for storage systems.

In traditionally regulated states, which have vertically integrated utilities both transmission and distribution and generation and have regulated consumer rates, states must develop Integrated Resource Plans (IRPs) as roadmap so forecasted energy demand can be met

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[54] Supra 10

[55] Energy Storage Association. "State Policies to Fully Charge Advanced Energy Storage: The Menu of Options." Energy Storage Association, July 2017. http://energystorage.org/system/files/attachments/state_policy_menu_for_storage_0.pdf.

in a cost-effective way.[56] States with deregulated markets, or markets in which the utility is decoupled from ownership over generation but maintains the transmission, distribution, and operations of the grid to the customer, are sometimes still required to file long term plans, as is the case in Texas, California, Illinois, and others.[57] IRPs and state filing requirements should be encouraged to consider storage as eligible technology in planning, and use the most up-to-date pricing information that incorporates the full value of storage from multiple revenue streams to reflect how competitive it is with other forms of generation. This should enable utilities that are considering new capacity additions in the form of gas or coal plants to ask if the demand they are looking to meet can instead be met with storage systems.

State regulatory bodies also play a significant role in local and statewide transmission and distribution. Interconnecting storage into a grid system that wasn't designed with this type of multifunctional resource in mind can be complicated, so it is important that state regulators establish new rules and limit uncertainty for interconnecting and managing storage. ESA recommends developing "clear rules, processes, and jurisdictional boundaries,"[58] clarifications on ownership options, providing transparency to distribution data, and better management for DERs.

Meanwhile, as the federal government lags on developing meaningful climate policy, states are forging ahead. To date, 29 states and Washington, D.C. have aggressive Renewable Portfolio Standards,[59] which will dramatically increase renewable penetration in those state markets. A responsible RPS should also include prudent storage planning that involves not only deployment goals, but also smart management and long-term considerations. As discussed, it is crucial that any energy storage plans be done with emissions considerations in mind. States should be doing cost-benefit analyses to account for emissions in new storage systems as they grow storage markets and should consider the most valuable ways to incentivize storage that will actually reduce emissions.

With proper eligibility parameters, states can use storage to meet RPS goals. In 2017, Nevada updated its RPS to 40 percent renewables by 2030, and counts energy delivered by qualifying energy storage devices towards meeting the requirement. To qualify, the storage system must benefit renewables in some way: either by charging from renewable generation that would otherwise be curtailed, or by performing ancillary services on the grid that enable higher integration of renewables.[60] Some states are developing storage mandates, but they must be careful to ensure that qualifying projects are actually driving emissions reductions. Oregon has a storage mandate (HB 2193) that requires the state's two main IOUs to have at least 5 MWh of

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[56] Girouard, C. (2015, August 11). Understanding IRPs: How Utilities Plan for the Future. Advanced Energy Economy Blog. Retrieved July 23, 2018, from https://blog.aee.net/understanding-irps-how-utilities-plan-for-the-future

[57] Wilson, Rachel, and Bruce Biewald. "Best Practices in Electric Utility Integrated Resource Planning: Examples of State Regulations and Recent Utility Plans." Regulatory Assistance Project, June 2013. www.raponline.org/wp-content/uploads/2016/05/rapsynapse-wilsonbiewald-bestpracticesinirp-2013-jun-21.pdf.

[58] Ibid.

[59] National Conference of State Legislatures. "State Renewable Portfolio Standards and Goals," February 2019. http://www.ncsl.org/research/energy/renewable-portfolio-standards.aspx.

[60] Assembly Member Brooks, Assembly Member Frierson, Assembly Member Yeager, Assembly Member McCurdy, Assembly Member Watkins, and Assembly Member Fumo. AB 206, Pub. L. No. AB 206 (2017). https://www.leg.state.nv.us/Session/79th2017/Bills/AB/AB206_R3.pdf.

energy storage capacity by 2020.[61] Its vague guidelines around whether "qualifying energy storage systems" will actually reduce emissions and its inability to assign value from multiple revenue streams to storage projects has led to slow implementation and analyses from Pacific Power showing energy storage to not be a cost-effective option.[62] Again, the goal here is not simply the deployment of as much storage as possible, but instead establishing frameworks for strategic, enduring, emissions-reducing storage deployment and management.

While the wholesale market must play a large role in ensuring that the nation's grid can develop a new system that properly manages and values energy storage systems, states will ultimately do much of the heavy lifting. It is crucial that state policymakers and regulators be informed and educated on energy storage, its nuances as an emission reducing technology, and its ability to integrate high levels of renewable energy onto the grid. States must work to ensure that energy storage is properly valued, that barriers to access in the market and the grid are addressed, and that they are enabling competition and considered fairly in resource planning.

CASE STUDIES

The following case studies analyze how states have incorporated storage as they seek to meet renewable energy goals. The case studies will examine legislation that states have put forward regarding energy storage goals in the context of renewable energy goals. Specifically, this paper will consider if legislation:

- Addresses the relationship between storage and VRE
- Provides definitions for renewable energy sources
- Provides definitions for energy storage, and whether it functions to promote renewable energy
- Establishes short term energy storage deployment goals
- Grants authority to state regulators to establish goals and innovation
- Includes consumer protections
- Establishes strong oversight and clear protocols from state agencies

[61] n.d. House Bill 2193 (2015). https://olis.leg.state.or.us/liz/2015R1/Measures/Overview/HB2193.
[62] Maloney, Peter. "Pacific Power Analysis Shows Storage Pilot Projects Currently Uneconomic." Utility Dive, April 28, 2018. https://www.utilitydive.com/news/pacific-power-analysis-shows-storage-pilot-projects-currently-uneconomic/522065/.

Illinois

Summary for Policymakers

Illinois passed two main pieces of legislation that had the potential to increase the amount of energy storage deployed in the state; the 2011 Energy Infrastructure Modernization Act (EIMA)[63] and the 2016 Future Energy Jobs Act.[64] Both bills were passed in the wake of financial disasters. In 2011, the Illinois General Assembly passed SB 1652 Energy Infrastructure Modernization Act (EIMA) to set forward a path for grid modernization in Illinois. Overall, this legislation was very vague in terms of introducing more renewables to the grid, and while the bill does mention storage, it is only in passing. There are no goals set forward, no timeline established and no entity is directed to ensure storage is being integrated. Furthermore, storage is not mentioned with renewable energy integration, and the bill does not specify that storage should be increased in order to increase the amount of renewable energy resources being used. However, the bill does offer some clarity regarding how reimbursements should be allocated for updates to the grid.

In 2016, the Future Energy Jobs Act was introduced and was, again, an example of industry interests impacting the integrity of a bill. Exelon, the parent company of local utility Commonwealth Edison Company (ComEd), had two nuclear plants operating in Illinois that were threatening to shut down and result in substantial job loss. The Future Energy Jobs Act promoted carbon-free energy (including nuclear), intended to create new jobs and sustain the jobs available at the two nuclear facilities, and bailed out the two failing nuclear plants operating in Illinois, resulting in a rate hike for consumers. The bill largely existed to rescue the state's failing nuclear plants coupled with the Illinois General Assembly's desire to reduce energy emissions. Again, this legislation did not discuss energy storage in any meaningful way.

Lessons Learned for Legislators

The heavy involvement of utilities in both these bills highlights the need for consumer protections. The influence of ComEd and Exelon defanged the legislation that was passed, making meaningful change difficult.

In a deregulated market, legislatures should be cautious of impending price hikes. The EIMA was created in the face of a 33% rate increase for consumers. This scenario allowed for ComEd to have significant influence in the formation of the bill.

Microgrids, while useful, are a method of deploying storage that puts the burden of payment largely on the consumer. This is not an effective way of deploying large scale energy storage and legislatures should be aware of the benefit this method has to utility companies at the expense of the consumer.

[63] Sen. Mike Jacobs, Sen. John Jones, Sen. John Milner, Rep. Kein McCarthy, Mike Bost, Dave Winters, Kenneth Dunkin, and Dan Reitz. Energy Infrastructure Modernization Act, Pub. L. No. 097–0616 (2011).

[64] Chaplin Rose, Christine Radogno, Donne Trotter, Neil Anderson, and Dave Syverson. Future Energy Jobs Act, Pub. L. No. 099–0906 (2016). http://www.ilga.gov/legislation/99/SB/PDF/09900SB2814lv.pdf.

Illinois Case Study

SB 1652 Energy Infrastructure Modernization Act

In 2011, the Illinois General Assembly passed SB 1652 the Energy Infrastructure Modernization Act (EIMA)[65] to set forward a path for grid modernization. Illinois' path to grid modernization is unique due to the energy market in the state. In the late 1990s, Illinois deregulated the electricity generation market in order to promote competition and reduce costs. In a regulated energy market, the utility owns all of the transmission lines and generates and sells electricity to customers. In 1997, the Illinois General Assembly passed the Electric Service Customer Choice and Rate Relief Law which required utilities in the state to divest their generation assets, the bill also allowed customers the ability to purchase energy generated from the supplier of their choice.[66] This law had dramatic impacts on the cost for both consumers and the utilities. The law reduced customer electricity prices by 20% from 1997-2001 and froze that rate until 2007.[67]

However, towards the end of the rate freeze, the deregulated market was going to cause rate increases of 33%, resulting in intense public backlash against deregulation. [68] During this tumultuous period, ComEd (the largest electric utility in Illinois) began rolling out its smart meter technology and ran into trouble as it filed to be reimbursed for its investments. Rate reimbursements are often, at least in part, put on the consumer. With a 33% rate hike looming, ComEd was looking at absorbing the cost of these investments. During this time, EIMA was being discussed in the Illinois General Assembly and ComEd lobbied hard for the bill, which would promote grid modernization and authorize rate recovery for utilities.

This bill worked to increase cybersecurity of the grid, stated a goal of integrating more renewable energy resources, deploying smart technologies for metering communications, deploying electricity storage, incorporating peak saving technology, reducing barriers to Smart Grid technology and improving the communication and interoperability of the grid. Overall, this was a very weak bill in regard to energy storage with little detail and direction included.

SB 2814 Future Energy Jobs Act

The Future Energy Jobs Act maintains Illinois' existing goal of 25% renewable energy by 2025 and also keeps a 2% cap on rate increases for customers.[69] However, this bill redirects the rate increases to go toward building more renewable projects; previously that money went toward purchasing credits to meet emission reduction goals in the state. While the bill does have very clear goals for wind and solar development in the state with clear directives and targets, it fails to detail any plan to promote storage despite its push to increase wind and solar in the state and did little to fund more renewables. This bill tasks the Illinois Power Agency (IPA) with

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[65] Sen. Mike Jacobs, Sen. John Jones, Sen. John Milner, Rep. Kevin McCarthy, Mike Bost, Dave Winters, Kenneth Dunkin, and Dan Reitz. Energy Infrastructure Modernization Act, Pub. L. No. 097–0616 (2011).
[66] Kevin Jones and David Zoppo, *A Smarter, Greener Grid: Forgin Environemental Progress through Smart Eenrgy Policies and Technologies* (Santa Barbara, California: ABC-CLIO, LLC, 2014).
[67] Ibid.
[68] Ibid.
[69] Chaplin Rose, Christine Radogno, Donne Trotter, Neil Anderson, and Dave Syverson. Future Energy Jobs Act, Pub. L. No. 099–0906 (2016). http://www.ilga.gov/legislation/99/SB/PDF/09900SB2814lv.pdf.

developing energy procurement plans for investor owned utilities (such as ComEd). This agency is also tasked with drafting contracts between utilities and suppliers to ensure "adequate, reliable, affordable, efficient, and environmentally sustainable electric service at the lowest total cost."[70] The IPA will submit its procurement plans to the Illinois Commerce Commission (ICC) for approval.

Importantly, Illinois' deployment of energy storage is not tied to renewables and has resulted in energy storage being used for natural gas storage.[71] The 2019 IPA procurement plan had one paragraph dedicated to energy storage and noted that while battery storage would help the state reach its renewable goals, it was still considered too expensive to deploy.[72]

Energy Storage, Microgrids, and a Restructured Market

A microgrid is a group of electricity sources that, while connected to the grid, can disconnect from the larger grid and function independently. Illinois claims it has been modestly deploying storage with microgrids to increase the amount of VREs in the state. However, most of its existing storage is used for natural gas,[73] not renewables.

Most of the storage deployment occurring in Illinois is in the form of battery storage to accompany microgrids. In 2017, ComEd announced that it would be launching a pilot program to test the use of battery storage throughout the state. The Community Energy Storage (CES) program is being conducted in Beecher, IL. This is part of its Community of the Future initiative which works to enhance communities by improving livability and efficiency through the smart grid. While ComEd claims that this will help integrate more renewable energy sources on to the grid, critics say that the project still relies heavily on natural gas. Meanwhile, DOE is providing several grants to promote the use of microgrids throughout the country, and ComEd has taken full advantage of these financial incentives, with \$5 million of the \$25 million Bronzeville project being funded by the DOE and ComEd has received a \$4 million grant to develop and test a system to integrate solar and battery storage with a microgrid.

Consumer and clean energy groups have played a large role in reigning in ComEd's attempts to gain more control and financial benefit from the deployment of microgrids in Illinois. ComEd put forward initial proposals for the Bronzeville microgrid project in which they requested ownership of the generation associated with the project.[74] However, Illinois' deregulated market does not allow utilities to own generation. Instead, utilities must purchase power from the market at the lowest available cost. After ComEd's proposal came under scrutiny from numerous organizations, they altered the proposal to allow a bidding process to determine ownership of the generation from the project.

[70] Ibid.
[71] Ibid.
[72] Illinois Power Agency. "Illinois Power Agency: ELECTRICITY PROCUREMENT PLAN 2019," January 2019. https://www2.illinois.gov/sites/ipa/Documents/2019ProcurementPlan/IPA-Final-2019-Procurement-Plan-4-Jan-2019.pdf.
[73] John, Jeff St. "Illinois Decision Opens the Path to Shared Utility-Customer Microgrids," March 1, 2018. https://www.greentechmedia.com/articles/read/illinois-decision-opens-the-path-to-shared-utility-customer-microgrids.
[74] Jeffrey Tomich. "GRID: ComEd's Chicago South Side Microgrid Hits a Nerve," January 22, 2018. https://www.eenews.net/stories/1060071515.

Meanwhile, the project posed serious concerns around rate hikes. In 2016, the Illinois legislature rejected ComEd's request for state funding for microgrids. In response, ComEd turned to consumers to foot the bill, submitting a request to the ICC to have ratepayers cover the cost of the $25 million microgrid project. The Attorney General railed against the decision to allow ComEd to rate base the $25 million the project is expected to cost.[75] While ComEd claimed that the cost per customer would be roughly a penny per month, the Attorney Generals' office calculated that based on the number of customers who will actually be served by the project, the cost would be closer to the outrageous sum of $400 a month for each customer.[76]

Ultimately, microgrids are a valuable investment and can help communities weather cybersecurity threats and natural disasters. However, in the case of ComEd, the pitch for microgrids was used to blur the lines of what a utility in a deregulated state can recoup as cost. ComEd tried to both lump VRE and storage integration into microgrids and argue that microgrid generation is part of the energy delivery system and therefore a regular utility expense that should be exempt from the competitive bidding process that takes place in deregulated markets. The work of consumer and environmental groups helped highlight problems with the proposal and rectified some of the most glaring issues with ComEd. However, stronger regulatory oversight is needed to ensure the consumers are not being swindled by utilities in efforts to promote clean energy and storage.

Summary

Illinois has not made significant strides in deploying energy storage despite its two bills that promote grid modernization and renewable energy targets. The grid modernization bill prioritizes the creation of microgrids at the expense of storage, a project that ComEd was already working on prior to the introduction and passage of this bill.

It is important to note that during the passage of EIMA consumers in Illinois were facing a 33% rate hike and legislators and the industry were eager to avoid shifting costs onto the consumers. This led to ComEd's involvement and endorsement of the legislation. The Clean Energy Jobs Act does not discuss renewable energy storage in any meaningful way. This bill also saw involvement from the industry as its passage was in part an attempt to bail out two failing nuclear plants in the state. The lack of focus this bill has on sustainable renewable energy growth has resulted in stagnated energy storage projects coming out of Illinois.

Overall, Illinois' legislation to encourage grid modernization and update their renewable energy portfolio fell short of resulting in meaningful energy storage. Both bills were heavily influenced by the utility and had very few specific goals set forward regarding the implementation of new renewable energy sources and both bills mention energy storage only in passing. The legislation was less a good-faith attempt to build out renewable energy and storage, and more a selfish attempt for the utility to enlarge profits, ultimately resulting in poor investment in energy storage.

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[75] John, Jeff St. "Illinois Decision Opens the Path to Shared Utility-Customer Microgrids," March 1, 2018. https://www.greentechmedia.com/articles/read/illinois-decision-opens-the-path-to-shared-utility-customer-microgrids.

[76] John, Jeff St. "Illinois Decision Opens the Path to Shared Utility-Customer Microgrids," March 1, 2018. https://www.greentechmedia.com/articles/read/illinois-decision-opens-the-path-to-shared-utility-customer-microgrids.

Furthermore, the meager gains made in energy storage deployment have come through the deployment of microgrids. There are few initiatives in place to make sure that energy storage is used to incorporate more renewables on to the grid. Additionally, the microgrid projects have been plagued by ComEd's attempts to recoup as much money as possible. The actions of ComEd and Exelon in both the legislative processes and working with the ICC have shown the need for consumer protections, regulatory oversight, and watchdog groups.

California

Summary for Policymakers

California has made tremendous gains in energy storage. The state passed two main pieces of legislation that impact renewable energy goals and energy storage; California's 100% Renewable Energy Bill (Senate Bill 100)[77] and its Energy Storage Bill (Assembly Bill 2514).[78] These bills had clear definitions regarding renewable energy sources, both state that the function of energy storage is to incorporate more renewables onto the grid, they include specific targets regarding deployment goals, and finally, they directed authority to major players. The clarity provided in this bill resulted in substantial energy storage deployment.

Under the direction of AB 2514 the California Public Utilities Commission (CPUC) worked to promote a clear pathway to meet energy storage goals through its roadmap, storage targets, and specific instruction to utility companies. With the CPUC requiring Investor Owned Utilities (IOUs) to acquire 1.3 GW of storage by 2020, California's current energy storage capacity is 332 MW, with 1,500 MW of energy storage procured or in the approval process.[79] In addition to the IOU requirements, California's publicly owned utilities (POUs) have deployed 59 MW of energy storage with an additional 224 MW expected to be installed by 2021. In 2017, the Los Angeles Department of Water and Powers' (LADWP) adopted a resolution that set an energy storage target of 178 MW by 2021.[80] The CPUC directed funding to promote these projects, and clarity from both the legislature and the CPUC has allowed utilities and the state to invest in projects to expand energy storage throughout California.

Lessons Learned for Legislators

Clearly defining that energy storage is being incorporated to accommodate an increase in renewable energy is vital to ensuring that projects deployed do in fact store renewable energy sources and not fossil fuel sources like natural gas.

Providing deadlines and clear goals regarding storage deployment gave the CPUC the authority to impose specific targets for different utilities including the IOUs, POUs, and the LADWP, resulting in 1,879.4 MW of energy storage currently in the approval process in California.

An active Public Utility Commission allowed for clear directives to be given to utility companies, resulting in 413.6 MW of energy storage throughout the state.

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[77] Kevin De León. SB 100 California Renewables Portfolio Standard Program: emissions of greenhouse gases., Pub. L. No. 399.11 of the Public Utilities Code (2018). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100.

[78] Assembly Member Nancy Skinner. Assembly Bill No. 2514: Energy Storage Systems, Pub. L. No. 2514, § 9620, Part 2 Division 1 Public Utilities Code (2010).

[79] California Energy Commission. "California Energy Commission - Tracking Progress," August 2018. https://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf.

[80] Ibid.

California Case Study

California is one of a handful of states that has a storage mandate. In June of 2011, California enacted Assembly Bill No. 2514, requiring the California Public Utilities Commission (CPUC) to establish affordable and effective energy storage targets by March 1, 2012.[81] After targets were established, the law gave IOUs three years to adopt the targets established by the CPUC.[82]

AB 2514 Energy Storage Systems

Assembly Bill 2514 was a grid modernization bill that defined what constitutes an "energy storage system". The bill explicitly states that expanding the use of energy storage systems must increase the amount of renewable energy resources on the grid.[83]

The bill lays out specific standards for storage systems, requiring that any energy storage system must be cost effective and reduce greenhouse gas emissions or reduce peak demand for electricity. The bill specifies that storage must be cost effective, and defines cost effectiveness as a system that "either reduce[s] emissions of greenhouse gases, reduce[s] demand for peak electrical generation, defer[s] or substitute[s] for an investment in generation, transmission, or distribution assets, or improve[s] the reliable operation of the electrical transmission or distribution grid."[84]

In response to AB 2514, the CPUC put forward a detailed timeline for storage investment and development requiring the state's IOUs to develop 1.3 GW of energy storage capacity by 2020.[85] By August 2018, the three largest IOUs in California[86] acquired or were seeking to acquire roughly 1,500 MW of energy storage in accordance with their targets related to AB 2514,[87] a significant increase over the 475 MW of capacity that came online the previous year. [88] The mandate and responding directive from the CPUC led to swift action from IOUs and electric utility companies around the state.

Bills following AB 2514 show that the California State Assembly has been steadfast in its efforts to build out its energy storage markets. The AB 2514 storage mandate allowed the CPUC to be engaged in storage deployment and put forward targets to utilities throughout the state. Throughout this process, the General Assembly was attentive to the development of energy storage deployment and passed several measures to help promote growth. In September 2016, the California State Assembly passed a new bill, AB 2868,[89] that required the CPUC to have the

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[81] Jones, Kevin, and David Zoppo. *A Smarter, Greener Grid: Foregn Environmental Progress through Smart Energy Policies and Technologies*. Santa Barbara, California: ABC-CLIO, LLC, 2014.
[82] Assembly Member Nancy Skinner. Assembly Bill No. 2514: Energy Storage Systems, Pub. L. No. 2514, § 9620, Part 2 Division 1 Public Utilities Code (2010).
[83] Ibid.
[84] Ibid.
[85] Ibid.
[86] PG&E, Southern California Edison, SDGE
[87] California Energy Commission. "California Energy Commission - Tracking Progress," August 2018. https://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf.
[88] Ibid.
[89] Gatto. Energy storage, Pub. L. No. AB 2868 (2016). https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB2868.

IOUs increase investment in programs to accelerate deployment of distributed energy storage projects across the state.[90] The increased energy storage demands from this bill are in addition to the targets laid out in AB 2514. Furthermore, in 2016 The California State Assembly passed AB 33,[91] which instructed the CPUC, along with the Energy Commission, to study the potential for long-duration bulk energy storage in the State to help integrate more renewable energy sources onto the grid.[92] Overall, the energy storage legislation in California has been clear, detailed, and has paved the way for quick energy storage deployment across the state.

Storage Deployed

Currently, California leads the nation in energy storage. Historically, California has primarily used its pumped hydro resources for storage; however, it seems unlikely that much more pumped hydro storage will be deployed due to siting issues and high capital costs.[93] Furthermore, hydropower projects larger than 50MW do not count toward the State's 1.3 GW energy storage goals.[94] California wants to promote innovation, and there is concern that relying too heavily on hydropower will stifle the growth of other technologies.[95] That said, in 2017, pumped hydro contributed more than 4,500 MW of energy storage in California, a 1,100 GWh increase from 2016.[96]

An interesting component of California's storage deployment is the role universities are playing. For example, Stanford University uses cold water to cool its buildings on campus and installed a new system that has three water towers for cooling.[97] Other universities are also experimenting with thermal energy storage. However, the contribution overall is minimal, and there is currently little investment to use this technology to meet the state's 2020 energy storage goals.

The California Energy Commission has funded flywheel storage system deployment in the state. Due to reductions in manufacturing costs, flywheel production has become a more viable option for energy storage in recent years. Flywheel technology is being researched and deployed through the Self-Generation Incentive Program (SGIP).[98] While not widely deployed, California is investing in this technology. Overall, battery storage remains the dominant figure in energy storage throughout California.

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[90] Ibid.
[91] Quirk. Electrical corporations: energy storage systems: long duration bulk energy storage resources, Pub. L. No. AB 33 (2016). https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB33.
[92] Ibid.
[93] Bracmort, Kelsi, Vann, Adam, & Stern Charles V. (2015). Hydropower: Federal and Nonfederal Investment. *Congressional Research Service*.
[94] Assembly Member Nancy Skinner. Assembly Bill No. 2514: Energy Storage Systems, Pub. L. No. 2514, § 9620, Part 2 Division 1 Public Utilities Code (2010).
[95] Edward A. Holt, and Todd Olinsky-Paul. "Does Energy Storage Fit in an RPS." Clean Energy States Alliance, July 2016. https://cesa.org/assets/2016-Files/Energy-Storage-and-RPS-Holt.pdf.
[96] Supra note 85
[97] Supra note 85
[98] Supra note 85

Battery Energy Storage in CA

Battery storage has made considerable gains in California, driven by the falling cost of batteries the state is expected to meet almost all its energy storage goals through the deployment of batteries. In 2017, stationary battery storage systems generated 177 MW of energy storage in California, a 30 MW increase from the previous year.[99]

In 2010, San Diego Gas & Electric (SDG&E) Borrego Springs Microgrid Demonstration Project used lithium-ion batteries to increase storage capacity. This project was funded through a US Department of Energy (DOE) and a California Energy Commission grant.[100] This microgrid currently has a 500 kW/1,500kWH, a 1,00kW/3,000kWh, and three smaller 50 kWh batteries.[101] Since its completion, the Borrego Springs Microgrid Demonstration Project has demonstrated its reliability to the surrounding community. In April 2013, during a wind storm, the microgrid provided power to 1,225 residents for 6 hours. In September 2013, 20 utility poles were damaged by a storm in the area, and the microgrid provided power to 1,060 residents for over 25 hours.[102] The microgrid has also provided power to the area during maintenance outages in May 2015, May 2016 and May 2018.[103]

In 2014, California installed the first two battery storage projects to participate in the state's electricity markets, the Vaca-Dixon and the Yerba Buena systems.[104] These two systems provide energy services to both Pacific Gas & Electric (PG&E) and the California ISO markets. Both these energy storage systems can provide up to seven hours of backup power to the grid.[105]

Funding for the development of battery storage projects has ranged from the DOE grants to the California Energy Commission. The California Energy Commission, in particular, has funded entire projects throughout the state in addition to providing grants. Having both federal and state funding has helped promote the deployment of battery storage technology throughout the state. Overall, battery energy storage systems have been growing in California. This growth has contributed to the CPUC's requirements to purchase new energy storage, improve performance, and reduce the cost of storage.[106]

Summary

California's Energy Storage bill provided specific targets and timelines for major actors to meet. The CPUC quickly established targets and deadlines for ISOs which prompted swift action from the utilities. California utilizes a variety of storage technologies, including pumped hydro, thermal storage, battery storage, flywheels, and compressed air storage. However, batteries have largely captured California's growing storage market. Major sources of funding

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[99] Supra note 85
[100] San Diego Gas & Electric. "BORREGO SPRINGS MICROGRID DEMONSTRATION PROJECT," October 2013. https://www.energy.ca.gov/2014publications/CEC-500-2014-067/CEC-500-2014-067.pdf.
[101] Supra note 85
[102] Ibid.
[103] Ibid.
[104] Ibid.
[105] Ibid.
[106] Ibid.

for energy storage projects in California, particularly battery storage, have come from the Energy Commission and the US DOE.

California's successes show that providing a clear definition for "energy storage systems" in legislation and stating that the function of energy storage is to increase the amount of renewable energy resources on the grid are necessary.[107]

[107] Supra note 80

Hawaii

Summary for Policymakers

Hawaii has a unique energy landscape because it is an island that consumes more energy than it produces. Hawaii's electric market is the most petroleum-dependent in the U.S, and Hawaii's heavy reliance on foreign oil played a huge role in Hawaii becoming the first state to set a 100% renewable goal. In 2015, Hawaii amended its Renewable Portfolio Standard and set the requirement of reaching 100% renewable electricity by 2045.[108]

Overall, Hawaii has invested heavily in energy storage. Prompted by the state's 100% renewable energy bill, Hawaii has heavily invested in battery storage operations to allow the better deployment of wind and solar. The Energy Commission and the DOE have funded many of these projects. The Hawaiian Electric Company (HECO) and the Kauai Island Utility Cooperative (KIUC) have proactively invested in energy storage projects throughout the island, and in some cases have developed goals of reaching 100% renewable electricity before the deadline established in law.

Hawaii also has self-corrected in terms of storage deployment. While the state initially had a heavy focus on investing in more renewables, it realized that deploying more renewables without storage was unsustainable. Since then, the Hawaii Public Utility Commission (HPUC) has led the way in promoting projects that pair renewables with storage. The utility companies have responded to the HPUC focus by submitting numerous wind and solar plus storage initiatives over the past few years. The HPUC's tariff to encourage solar plus storage through the Smart Export program is one example of a public utility commission working with utilities to make the grid more resilient.

Lessons Learned for Legislators

Hawaii's 100% renewable energy bill was extraordinarily brief- nine pages. There was no mention of storage in this legislation. Effective legislation, as we have seen from California is detailed and gives clear instructions to all parties involved (PUCs, utilities, etc.). The successful deployment of renewable energy in Hawaii was due to its unique energy landscape and not because a thoughtful and clear bill was passed.

Hawaii energetically started deploying more renewable energy after the passage of this bill. However, grid reliability became threatened as many circuits across the islands could only tolerate more distributed solar during peak demand. The HPUC quickly worked to fix this problem by promoting projects that paired solar with storage. The takeaway here is that renewable energy bills *must* pair renewable energy deployment with storage.

The legislation, while short, does indicate the HPUC will be an authority for the utilities to look to and work with while meeting renewable energy goals. The HPUC has led the way in promoting projects that deploy renewables with storage and have been a major player in funding large projects.

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[108] Energy Information Administration (EIA). "Hawaii - State Energy Profile Analysis - U.S.," November 2018. https://www.eia.gov/state/analysis.php?sid=HI#5.

Hawaii Case Study

Hawaii’s heavy reliance on foreign oil played a huge role in Hawaii becoming the first state to set a 100% RPS. In 2015, Hawaii amended its RPS and set the requirement of reaching 100% renewable electricity by 2045.[109] Petroleum-fired power plants have supplied a majority of Hawaii’s electricity generation for decades. This costly process is done virtually nowhere else in the United States. In 2017, Hawaii’s petroleum made up 2/3 of Hawaii’s electricity generation down from ¾ in previous years.[110] Additionally, in 2017, renewable energy sources supplied more electricity than coal for the first time.[111] Both the importation of petroleum for electricity and the small-scale separate grid systems have caused Hawaii to have some of the highest electricity prices in the U.S. Interestingly, Hawaii has the lowest consumption in the nation, both in terms of total consumption and per capita consumption.[112]

Hawaii’s six islands each have their own electricity grids that are operated by individual electric utility companies or cooperatives. While Hawaii is looking into ways to better connect the islands grid systems it has not made progress on this initiative.

Hawaii’s 100% Renewable Energy Portfolio

The goal of Hawaii’s 100% RPS was to make the state more energy independent by achieving 100% renewable energy by 2045. This bill instructs the HPUC to create a ratemaking structure that incentivizes Hawaii’s utilities to invest in renewables. The nine-page bill also instructs the public utility commission to evaluate the state’s renewable portfolio every five years and report its findings to the legislature.

In response to the new RPS, HECO drafted a Power Supply Improvement Plan (PSIP) in 2016 that put forward a comprehensive and aggressive energy plan to help meet the State’s 100% renewable goals; this plan goes until 2021. The PSIP would accelerate the states renewable goals and achieve 52% renewable energy by 2020.[113] HECO is working toward the goal of having the island of Molokai to achieve 100% renewable by 2020 and having this be a test run for future islands. The PSIP indicates that stakeholders will be involved in helping Hawaiian Electric meet its goals. In particular, this plan calls on Paniolo Power to invest in energy storage research and how to best integrate it with wind energy. The plan recognizes that in order to increase renewable energy on the islands, the grid will need critical updates, especially storage. Molokai recognizes the need for storage and points out that falling prices for battery storage will help the island reach its goal of 100% renewable by 2020.[114]

Storage Deployed

Unlike California, Hawaii does not have specific storage goals set; however, the two states do have similar types of energy storage deployment. Like California, Hawaii is not

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109 Ibid.
110 Ibid.
111 Ibid.
112 Ibid.
113 “Power Supply Improvement Plan,” accessed March 28, 2019, https://www.hawaiianelectric.com/clean-energy-hawaii/integrated-grid-planning/power-supply-improvement-plan.
114 Ibid.

aggressively developing pumped hydro storage. Kauai Island Utility Cooperative (KIUC) is developing a 25 MW hydroelectric storage project on Kauai to integrate with solar farms. While this is the only project currently under development, other reservoirs in Maui and Oahu have been noted for their potential storage use. However, upfront costs and environmental concerns make it unlikely that Hawaii will see a significant surge in pumped hydro storage.[115] Batteries dominate the energy storage market in Hawaii. The state has several initiatives to promote battery storage in the state.

Hawaii has incredible potential for solar thanks to its incoming solar radiation levels and strong state renewable energy policies. Without storage, solar power is not available during the evening when demand for electricity is high. Whereas, electricity is plentiful during the day when demand is much lower. In Hawaii, the high level of renewables has made the duck curve more pronounced than it is in other locations. In order to address the problem the duck curve represents, storage must be deployed in conjunction with renewables.

In 2017, The Hawaii Public Utilities Commission (HPUC) ordered the Smart Export Solar Tariff. This order was in response to a problem that was occurring in Hawaii at the time. First, utilities were worried about grid reliability, solar penetration in some areas was sitting at 20% and many circuits across the islands could only tolerate more distributed solar during peak demand. HPUC responded by lowering the rate of compensation for solar owners that export electricity to the grid from $0.27/kWh to $0.15/kWh.

The Smart Export Program is an initiative that allows citizens to install rooftop solar (or other renewable systems) and a battery storage system.[116] This program provides incentives to citizens in order to develop more rooftop solar. Once a customer installs a rooftop solar system and a battery storage system, they are expected to charge their battery during the day from 9:00 am - 4:00 pm and use that energy to power their homes in the evening.[117] Customers are eligible to sell energy to the grid during the evening if they exceed what they need. However, energy exported to the grid during the day is not compensated. For the time being, this program is capped at 25 MW or between 3,500-4,500 customers.[118]

Moving forward, the HPUC recognized that deploying solar without storage was not sustainable and changed course to encourage more storage deployment. This is an important lesson as more states established renewable energy goals. In order to successfully incorporate renewables on to the grid, they must be deployed with storage.

Another program that is promoting energy storage is SEAMS (Integrating System to Edge-of-Network Architecture and Management) for SHINES (Sustainable and Holistic Integration of Energy Storage and Solar PV). HECO is participating in a $2.43 million research project funded by the US DOE. HECO will work to deploy solar energy storage across Hawaii.

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[115] Supra 92

[116] Hawaiin Electric. "Smart Export." Hawaiin Electric Company, n.d. https://www.hawaiianelectric.com/products-and-services/customer-renewable-programs/smart-export.

[117] Ibid.

[118] Ibid.

This project is part of a US DOE initiative SEAMS for SHINES that works to better integrate solar and storage systems.[119]

There are a number of programs and initiatives throughout Hawaii promoting energy storage, but many utilities are also investing in storage on their own. While HECO is engaging in SEAMS for SHINES, they are also deploying their own energy storage. In October 2018, HECO announced seven solar plus storage projects for the Islands of Oahu, Maui, and Hawaii Island. These projects consisted of:[120]

- Three storage projects for Oahu totaling 12 MW of storage.
- Two storage projects for Maui totaling 75 MW of storage.
- Two storage projects for Hawaii Island totaling 60 MW of storage.

In total, these projects would result in 247 MW of solar energy and over 1 GWh of energy storage throughout the state.

HECO has also requested two rounds of funding from the HPUC. In May 2018, HECO applied for $2,500,000 for a Contingency & Regulating Reserve ("CRR") Battery Energy Storage System ("BESS") project.[121] This project would develop a 100 MW battery energy storage system at HECO's Campbell Industrial Park Generating Station.[122] The total cost of the project is estimated to be $104 million and construction will begin in October 2019, with the expected completion date in October 2020.[123] The funding application is currently under review by the Commission.

In May 2018, HECO requested a second round of funding from the HPUC for $2,500,000 for the development of an energy storage battery. This project would develop a 20 MW battery capable of storing 80 MWh of energy and would be developed at the West Loch Naval Annex that has been leased from the United States Navy for HECO's West Loch solar photovoltaic project.[124] Project construction is scheduled to start in October 2019 with an expected completion date in February 2020. The total estimated cost of the project is $43.5 million.[125] The funding application is currently under review by the Commission.

HECO is also working to deploy other types of energy storage, not just batteries. HECO in partnership with Amber Kinetics' deployed a flywheel storage system that can store up to 4 hours of energy. It is an 8kW system that began operation in 2018 on the island of Oahu. [126]

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[119] Department of Energy, "PROJECT PROFILE: Hawaiian Electric Company (SHINES)," Energy.gov, N.D, https://www.energy.gov/eere/solar/project-profile-hawaiian-electric-company-shines.
[120] Hawaii Public Utiltiy Commission, "State of Hawaii Public Utilities Commission Annual Report for Fiscal Year 2018," December 2018, https://puc.hawaii.gov/wp-content/uploads/2018/12/FY18-PUC-Annual-Report_FINAL.pdf.
[121] Ibid.
[122] Ibid.
[123] Ibid.
[124] Ibid.
[125] Ibid.
[126] Department of Energy, "Hawaii Renewable Energy Projects," accessed March 31, 2019, https://energy.ehawaii.gov/epd/public/energy-project-details.html?rid=4b--5792b87354cc02b.

HECO is aggressively pursuing energy storage deployment in Hawaii, but it is not alone. KIUC is a not-for-profit cooperative, so its revenue is either invested back into the grid or returned to its members. Every customer is a member and co-owner of the utility. In 2015, KIUC entered into a 20-year power purchase agreement with Tesla. Tesla has a 13 MW solar farm with a 52MWh lithium-ion battery storage system.[127] The battery will provide electricity during evening peak, which will allow KIUC to reduce its dependency on fossil fuels.[128] The declining cost of batteries has made battery energy storage the most viable option for states to use. In addition to the partnership with Tesla, KIUC, in partnership with AES, is deploying a 19.3 MW direct current (DC)/ 14 MW alternating current (A/C) solar farm along with a 70 MWh battery energy storage system at Barkings Sands, a 140-acre area of land leased from the US Navy.[129]

The HPUC has approved a number of storage programs throughout the state and has many applications pending. In 2018, the Commission approved KIUC's application for a 14 MW solar power system along with a 70 MWh Battery Energy Storage System.[130]

Summary

While Hawaii has been very successful in implementing renewable energy sources and after some adjusting has also been a leader in incorporating renewables plus storage, there were growing pains that could have been avoided had the legislature put forward a detailed and comprehensive bill. Even though Hawaii has been successful in implementing renewables, other states should not assume that putting forward a vague 100% renewable energy bill will be successful.

The market in Hawaii favors renewables in a way that would not be possible in states that are not isolated islands with a dearth of their own energy resources. The economic incentives in this state to invest in renewables are not present in any other state. This unique situation has allowed their vague 100% renewable bill to result in action. As we have seen in Illinois that is not always the case as Illinois' renewable bill resulted in very little energy storage being deployed and few safeguards from industry involvement. That being said the legislative mandate from the Hawaii General Assembly directing the HPUC to accomplish 100% renewable targets has resulted in robust funding opportunities for storage projects.

Overall, Hawaii has invested heavily in energy storage. Prompted by the state's 100% RPS bill Hawaii has heavily invested in battery storage operations to allow better deployment of wind and solar. The HPUC and the U.S. DOE have funded many of these projects. HECO and KIUC have proactively invested in energy storage projects throughout the island and in some cases have developed goals of reaching 100% renewable electricity prior to the deadline established in law. Hawaii has also self-corrected in terms of storage deployment. While the state initially had a heavy focus on investing in more renewables it realized that deploying more

[127] Peter Maloney. "Leading Edge: Hawaii Utilities Push Storage, Solar Integration for 100% Renewables Mandate." Utility Dive, March 21, 2016. https://www.utilitydive.com/news/leading-edge-hawaii-utilities-push-storage-solar-integration-for-100-ren/415931/.
[128] Ibid.
[129] Supra note 121
[130] Supra note 115

renewables without storage was unsustainable. Since then, the HPUC has led the way in promoting projects that deploy renewables with storage. The HPUC's tariff to encourage solar plus storage through the Smart Export program is one example of a public utility commission working with utilities to make the grid more resilient. The utility companies have responded to the HPUC by submitting numerous wind and solar plus storage initiatives over the past few years.

Conclusions: A Toolkit for Policymakers and Regulators

Energy storage is generally understood to have the ability to act as an enabler of renewable energy, which in turn must displace emissions-producing fossil fuels that exacerbate climate change. However, our review shows that deliberate frameworks must be designed to build out the storage industry in a way that will lead to emissions reductions and encourage renewable energy growth. As Hittinger states, "[p]olicymakers should be aware that the direct emissions effect of adding storage to the grid is neutral at best and that its environmental benefits are dependent on its ability to encourage new renewable electricity generation." Energy storage, like all climate solutions, is not a silver bullet to solving the climate crisis, but rather one important piece of the decarbonization puzzle. Smart energy storage buildout could mean transformation of the electricity sector, but energy storage can just as well benefit fossil fuel resources as it can renewables without proper structure to develop an industry with the long-term goal of enabling very high renewable energy penetration on the grid.

Today, in most parts of the United States, the need to curtail renewable energy is not a salient issue. However, in places like Hawaii and California, grid operators are contending with the "duck curve" and beginning to see serious need for load-shifting and better systems to smooth out demand over generation curves. If the US chooses to take the threats of climate change seriously and embark on real decarbonization pathways, many more states will soon need to confront intermittency issues of VREs as they reach high penetration levels on the electric grid. Rather than wait until that time comes, it makes sense for the nation to start building out the nascent energy storage industry in an effective way and with clear intention. Policymakers should resist the urge to design policy that simply builds out storage markets as fast as possible in the short term without regard to thoughtful design. A perfunctory policy implementation without clear goals and guidelines spells disaster for decarbonization plans. The goal for storage markets should not simply be building out as much storage technology as possible, as is the case with renewable energy targets, but rather, designing storage markets with a framework that sets them up to help displace fossil fuel resources and enable renewables growth, balance their potential emissions increases, and succeed as the grid's primary flexible load capacity in the decades to come.

The conclusions of our review cover approaches for deliberate policy and regulatory design of the energy storage market, including aspects that can be broadly considered and applied, federal and state level functions, and different approaches that may be necessary depending on state wholesale market design. We encourage policymakers, regulators, clean energy advocates, and industry leaders to consider these options as the energy storage market develops.

Elements and strategies for broad application:

Policy makers and regulators at both the federal and state level have a large responsibility to ensure the success of a thriving energy storage market that achieves its purpose as an enabler of renewable energy growth and emissions reductions.

Federal regulators

At the federal level, FERC's Storage Rule (Order 841), has provided an extremely useful framework for designing new market rules that will properly value storage for all its revenue streams. FERC's role here is to ensure that storage can meet accurate price signals in the wholesale market so that it can compete, be properly compensated for its values, and displace unnecessary new fossil fuel infrastructure whenever possible. The importance of FERC's role in requesting clarity from RTO/ISOs on energy storage participation models is critical to the growth of this industry, but it is ultimately up to the RTO/ISOs and grid operators to determine participation models and revenue streams to allow storage to compete.

By granting flexibility to RTO/ISO design, FERC allows autonomy to these operators to develop plans that suit their region best. However, it is important that as FERC reviews case filings, it (a) ensures that proposals actually allow for market competition, (b) ensures that proposals fairly compensate storage technology, (c) sticks to a timeline and pushes for swift implementation of participation models. That last point often tends to be a sticking point for federal regulation - while FERC has presented deadlines, some grid operators are already requesting implementation extensions. While extensions may be granted on a case-by-case basis, the urgency of the larger picture should not be forgotten, and both grid operators and FERC should look to removing unnecessary bureaucratic roadblocks throughout this process in favor of efficient, swift program implementation.

Currently, FERC's base requirements for RTO/ISO storage participation filings do not have any requirements around ensuring that storage deployment will be built out in a way to promote the growth of renewable energy and enable carbon emissions reductions. While a requirement such as this is outside FERC's jurisdiction, grid operators should be encouraged to implement emissions reductions into value streams and create requirements for themselves about charging sources for storage. If there is no recognition of emissions by way of revenue streams from RTO/ISOs, this task will fall mainly on the states.

State regulators

State regulators also play a critical role in effectively deploying energy storage in a way that actually leads to emissions reductions, while ensuring that accurate price signals for energy storage extends to the retail market. As PUCs and other utility oversight entities establish clear protocols for energy storage to be distributed to end-users, it may also fall to them to establish interconnection rules and jurisdictional boundaries. State regulators will hold much of the responsibility to overcome logistical challenges to storage interconnection, establish ownership options, create long term deployment plans, and figure out best practices for managing DERs. Finally, it will likely fall on the states to design cost-benefit analyses in regard to emissions reductions.

While the wholesale market should internalize any emissions changes due to new storage, state regulators will have the authority to approve new projects and can look to emissions analyses to determine how beneficial a storage system will actually be to decarbonization. In order to tackle these myriad responsibilities, state regulators should now begin to convene for educational and strategy-oriented conferences and meetings. Regional information sharing between states may provide value as leaders determine best practices for other states to follow. Establishment of a uniform emissions analysis tool, perhaps created by a federal agency, that can be applied to multiple states, would be a great assist in helping state regulators with decision making for new storage capacity deployment.

State and federal policymakers

Legislation that contains a clearly defined function of energy storage to facilitate the use of renewable energy on to the grid is vital. Some states do not invest in energy storage for the purpose of promoting renewable energy, or if they do it is not explicitly stated in law. This has had the impact of increased emissions in some parts of the country.

Robust and successful renewable portfolio standards have increased the need for storage in states like Hawaii and California and will likely do the same in other states as they work to meet their clean energy goals and achieve high integration of VREs. Storage deployment is strongest in states that have a detailed plan for storage incorporation, but states that are moving forward with 100% renewable goals will need to invest in storage as their electricity generation fractions approach 40% VRE. Legislation that directs the PUC to cooperate with utilities to increase storage has much higher rates of deployment compared to states with vague storage regulations and policy. On the federal level, tax credits such as the ITC have been shown to help stimulate project development in the renewable energy sector. A storage ITC could be a useful tool in kick starting storage markets, but implementation should consider stronger benefits for those projects that actually lead to emissions reductions. Meanwhile, federal and state funding opportunities are important for both the R&D and deployment stages for energy storage. In both California and Hawaii, we have seen DOE investment as well as funding from the PUCs. HECOs participation in the SEAMS for SHINES program is an excellent example of states taking advantage of federal funding opportunities.

Hawaii's story of integrating high levels of VRE without considering storage cautions that an ambitious RPS that doesn't consider addressing the variability of VREs will ultimately need to be slowed and re-oriented. In Hawaii, solar industry growth was slowed as grid reliability became a concern. In order to avoid this fate, state and federal policymakers should take care to include storage in any legislation that increases VRE to electricity generation fractions approaching 40% or higher. While storage is not necessary in most parts of the country at this time, the wise economic and policy decisions involve being prepared early with good storage frameworks. Furthermore, storage should not be assumed to simply increase renewables growth and decrease carbon emissions; these goals need to be stated explicitly. Although Illinois has seen an increase in storage projects, albeit modest, those projects are largely charged by natural gas. Coupling storage with renewables with the intention of rescuing power that would otherwise be curtailed is key to ensuring that storage actually displaces carbon-emitting resources.

Consumer protections, end user compensation for DER

Illinois' investor-owned utilities exemplified concerns over consumer protections that can come with new electricity markets and technology. In 2011, a previously authorized rate suppression was expiring resulting in a 33% rate hike for consumers, and in 2016 two nuclear facilities were closing because they were not competitive in the market. In both these instances, legislation was needed to correct these looming disasters, and energy storage proposals were wrapped into rate cases that could have caused issues for customers. Legislators should work to ensure that utilities do not take advantage of vulnerable situations at the expense of ratepayers.

The time sensitive nature of these problems allowed the industry, in this case ComEd and Exelon, to have undue influence on the proposed legislation. This negatively impacted both the technical detail of the law as well as the substance. Fortunately, watchdog and consumer protection groups stepped in, but it is crucial that policymakers and regulators be wary of the risks to consumers as the energy storage market opens up new opportunities for ownership.

Considerations for future studies

Currently, there is not robust analysis to help us attribute renewable energy growth to energy storage deployment. While there is a clear symbiotic relationship between VREs and storage, and additional storage may enable new renewable energy deployment that results in an indirect reduction in carbon emissions, there is a lack of evidence showing this exact pathway in action, and few ways to measure decision making processes to displace emissions generating power sources with renewable energy thanks to the existence of energy storage. Much of renewable energy industries' support for storage is predicated on the idea that storage is an engine driver for solar and wind. However, with little research to support this claim, it may be difficult for these industries to push for storage friendly policies and understand the impact this technology may have on renewable energy growth. This is not to say this claim isn't true, but it should behoove researchers in this space to do regression analyses on storage attribution to renewable energy growth. Due to the current low sample size of storage projects built in tandem with renewable energy, a study of this nature may need to use predictive elements or explore specific states, such as California, that have seen more significant storage growth than the rest of the country.

Renewable energy, especially at high levels, can give a price signal that would drive the demand for more energy storage. Both California and Texas have seen their electricity prices fall negative due to a glut of solar and wind at certain times. The value of this electricity production could be captured if storage systems were present. It would be valuable to understand exactly how much electricity is curtailed and lost versus rescued via storage depending on variables such as no storage system, non-co-located systems, and co-located systems. Future studies could experiment with different inverter efficiency levels, technology types, and integration with demand response and other smart grid applications.

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